PROPOSAL

UHF Solid-State Preselector Design Study

Prepared for Department of the Navy
Naval Electronic Systems Command
Washington, D. C. 20360

Russell W. Hanson

Steve F. Russell

David B. Hallock

Front-End Design Group, Telecommunications Department

Collins Radio Company
1969
Cedar Rapids, Iowa

Steve Russell

COLLINS

proposal

Collins Radio Company

UHF Solid-State Preselector Design Study

523-0761575-00181P
11 March 1969

COLLINS

proposal

UHF Solid-State Preselector Design Study

Prepared for Department of the Navy
Naval Electronic Systems Command
Washington, D. C. 20360

Bid Request No. 8678

"This data shall not be disclosed outside the government or be duplicated. used or disclosed in whole or in part for any purpose other than to evaluate the proposal, provided that if a contract is awarded to this offeror as a result of or in connection with the submission of such data, this legend shall be of no force or effect; and in such event this offeror will assert no rights against the government with respect to this data, unless based on patents or provisions in the contract. This restriction does not limit the government's right to use information contained in such data if it is obtained from another source."

©Collins Radio Company 1969
Printed in the United States of America

Collins Radio Company | Cedar Rapids, Iowa

BLANK PAGE

table of contents

Page

Section 1 Introduction 1-1

Section 2 Detailed Study Plans 2-1

2.1 Literature Search 2-1
2.2 Front-End Design Principle Review 2-1
2.2.1 Theoretical Analysis 2-2
2.2.2 Discrete and Hybrid Circuit Testing 2-3
*2.3 Fabrication Methods 2-4
*2.3.1 Basic Processes 2-4
*2.3.2 Active Components 2-7
*2.3.3 Passive Components 2-9
*2.3.4 Packaging 2-11
*2.4 Tuning Methods 2-15
*2.4.1 Electrical Tuning 2-16
*2.4.2 Resonator Types 2-16
2.5 New Component Requirements 2-17
*2.6 Circuit Considerations 2-18
*2.7 Environmental Considerations 2-18
2.8 Trade-Off Analysis 2-18

Section 3 Project Time Schedule 3-1

Section 4 Personnel Assignments 4-1

Section 5 Facilities 5-1

5.1 Research and Development Facilities 5-1
5.1.1 Laboratories 5-1
5.1.2 Measurements and Standards 5-2
5.1.3 Model Shop 5-2
5.1.4 Chemistry and Plastics 5-3
5.2 Related Manufacturing Facilities 5-3
5.2.1 Microelectronics 5-3
5.3 Services 5-13
5.3.1 Computer Facility 5-13
5.3.2 Libraries 5-13

list of illustrations

Figure		Page
2-1	Basic Superheterodyne Front-End Block Diagram	2-2
2-2	Preselection and Interstage Filter Losses for Constant Input Noise Figure	2-2
2-3	Image Phasing Mixer	2-4
2-4	Fabrication Methods	2-5
2-5	Equivalent Circuits and Typical Properties of Two Bipolar Transistors Connected as Diodes in Monolithic Integrated Circuits	2-8
2-6	Thin-Film Flat Spiral Inductor	2-9
2-7	Simplified Equivalent Circuit of a Typical Monolithic Diffused Resistor Showing Parasitic Elements and Valves	2-10
2-8	Calculated Frequency Dependence of a 10 Kilohm Resistor Fabricated Using Well Known Thin-Film and Diffusion Techniques	2-11
2-9	UHF RF Amplifier-Mixer Using Thin-Film Hybrid Construction	2-13
2-10	UHF Injection Oscillator With Crystal Control on Thin-Film Substrate	2-14
2-11	Input Filter Tuning and Resonator Design and Fabrication Considerations	2-15
2-12	Comparisons of Maximum Available Q for Five Different Inductance or Resonator Techniques in the UHF Band (Maximum Theoretical Q for a Given Constructional Volume)	2-17
2-13	Image Attenuation Versus Intermediate Frequency	2-19
5-1	Engineering Lab	5-1
5-2	Screen Room	5-1
5-3	White Room	5-2
5-4	Collins 100 kHz Frequency Standard	5-2
5-5	Section of Engineering Standards Laboratory Showing Some of the Equipment Available for Special Measurement Problems	5-3
5-6	Typical Thin-Film Hybrid Circuits	5-5
5-7	Hybrid Thin-Film Manufacturing Operations	5-6
5-8	Micromodule Constructions	5-8
5-9	Micromodule Production	5-10
5-10	Standard Micromodules	5-11
5-11	Collins MOS Large Scale Integrated Digital Logic Array (Die Chip Measures 0.125 by 0.095 Inch)	5-12
5-12	Computer Facilities	5-13

Section 1

Introduction

This proposal has been prepared by the Cedar Rapids Region of Collins Radio Company in response to Naval Electronic Systems Command RFQ N00039-69-Q-2043(Q) and describes the plan for exploratory development and design of circuits and techniques fundamental to a uhf rf preselector. This study is to advance the state-of-the-art in application of microelectronic principles to the eventual development of uhf (225 to 400 MHz) front ends capable of extreme miniaturization while providing useful performance characteristics. The study is to include a comprehensive literature search, a short review of superheterodyne front-end design principles related to the uhf spectrum, an analysis of tuning methods, a performance trade-off analysis, and the specification of advanced components necessary for development of an integrated electronically tuned front end. The study will be constrained to those areas which may be implemented through multiphase monolythic silicon technology, compatible thin-film processes, hybrid circuits, or any combination thereof.

Collins has considerable interest and ability in the area of this study. Collins has a long history of uhf development resulting in equipments with extensive military usage such as the AN/ARC-27, AN/ARC-52, AN/ARC-51, and AN/ARC-109. The latter is an all solid-state design except for the rf power amplifier and uses many microelectronic circuits in its digital synthesizer, if amplifiers, and audio stages. The Company's interest in providing very high performance uhf communication has recently resulted in the development and production of the U-1000 series of equipment which are capable of flexible air and ground system configuration.

Collins utilizes the functional engineering approach to research and development wherein design specialist groups develop the major subsections of an equipment. These functional engineering departments and groups maintain Company-sponsored study programs within their specialty area to improve their design techniques and knowledge. The proposed study will be done within a tuner functional engineering group which has had extensive experience in uhf design. This experience is supported by other specialists in the areas of thin-film, integrated circuit, and microwave design. The large diversification of abilities throughout the Company's major locations in Cedar Rapids, Iowa; Dallas, Texas; and Newport Beach, California, give Collins a capability for a thorough examination of the study proposed.

BLANK PAGE

Detailed Study Plans

The following paragraphs discuss the areas to be examined in the course of the study program. Emphasis will be placed on extensive examination of circuits, techniques, and solid-state phenomena which hold promise for microminiaturization. Cursory dismissal of an area on the basis of inadequate examination will be avoided by analysis of the circuit or technique involved with respect to its effect on the overall performance of a uhf tuner. The first step in the study, therefore, will be a comprehensive literature search.

2.1 LITERATURE SEARCH

The services of the Collins Research and Development library will be employed in making a thorough search of existing literature. The resources of this library are described in the facilities section of this proposal and are quite extensive. The major topics to be retrieved from the literature are as follows:

a. Uhf and microwave microminiaturization.
b. Lumped constant resonators.
c. Distributed constant resonators.
d. Molecular resonance effects.
e. Thin-film and hybrid construction techniques.
f. Uhf integrated circuits.

It is to be expected that additional topics will become apparent as an early result of the search.

Extensive use is planned of the abstracting services available including the following:

a. The Engineering Index.
b. Applied Science and Technology Index.
c. Electronics Abstracts Journal.
d. Science Abstracts, Section B - Electrical and Electronics Abstracts.
e. Solid-State Abstracts.
f. Technical Abstract Bulletin (DDC).
g. US Government Research and Development Reports (DDC).
h. Scientific and Technical Aerospace Reports (NASA).
i. National Referral Center, Library of Congress.

Additionally, Collins has an internal documentation system which makes all material published by company personnel available with very short access time. It is to be expected that a multiplicity of references to a given article will appear during the search.

2.2 FRONT-END DESIGN PRINCIPLE REVIEW

The optimal design of a receiver front end requires knowledge of many relationships between the major blocks of the circuit, the components, and the relative weights assigned to the various performance specifications. It is the purpose of this part of the uhf front-end study to present an analysis of the fundamental relationships and to examine the block diagram parameters and circuit performance with regard to microminiature design. The work will consist of the following two major areas:

a. Theoretical analysis.
b. Discrete and hybrid circuit testing.

2.2.1 Theoretical Analysis

A simple block diagram of a receiver front end is shown in figure 2-1. There are several theoretical areas which must be examined to achieve the best performance specifications as constrained by the characteristics of microminiature components and circuits. The sensitivity of a receiver is definable in terms of its input noise figure and bandwidth. If the mixer noise figure is low enough, it is clear that an rf amplifier is not necessary. The amplitude of an undesired signal which is within the rf passband would therefore be less at the mixer than if an rf amplifier were present. This trade-off will be examined in the study.

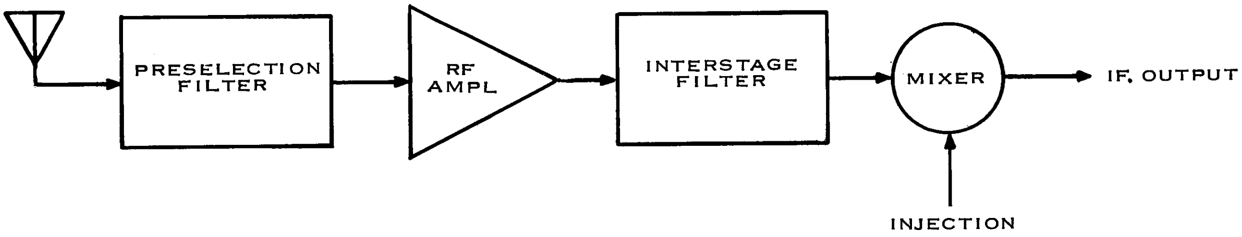


Figure 2-1. Basic Superheterodyne Front-End Block Diagram.

When an rf amplifier is required, the allocation of selectivity between the preselection and interstage rf filters requires study. If the total number of resonators in the front end is held constant, then there are trade-offs concerning the number of resonators in each rf filter. When the Friis equation for the noise figure of cascaded stages is applied to the basic block diagram in figure 2-1, it can be found that there is a functional relationship between the flat losses of the rf filters that must be satisfied to result in a given input noise figure. Such a relationship is sketched in the plot of figure 2-2. Filter theory can be used to relate the passband loss with the stopband selectivity; therefore, a trade-off study can be made resulting in an optimal distribution of selectivity.

Another topic which requires analysis is the spurious response performance of a microminiature front end. The constraints leading to selection of the intermediate frequency must be examined together with considerations of down or up conversion. For a given frequency conversion scheme, application of the general mixing equation

$$Hf_H + L f_L = f_o$$

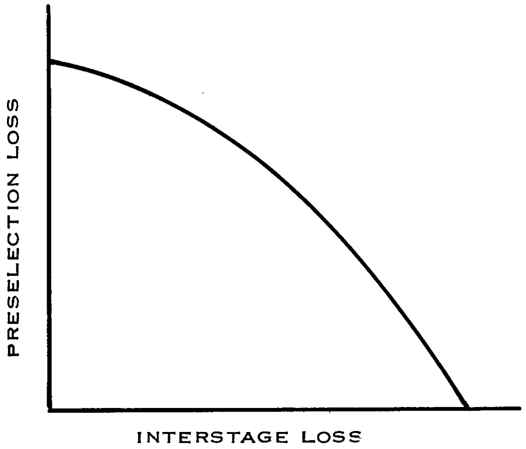


Figure 2-2. Preselection and Interstage Filter Losses for Constant Input Noise Figure.

using either graphical or computer aids, will predict the spurious response frequencies. In this equation, H and L are integers associated with the high and low frequency inputs to the mixer and f_o is the output frequency.

It is to be expected that large rf stopband attenuation will be difficult to obtain in monolithic construction. The image phasing mixer whose block diagram is illustrated in figure 2-3 will be analyzed to define the circuit components required to achieve satisfactory performance over the 225 to 400 MHz band. The mathematical analysis of this type of mixer is relatively straightforward. Let

$$e_a = A \sin \omega_s t$$

$$e_{LO} = B \sin \omega_{lo} t$$

The 90 degree rf phase shift causes the signal input to the upper mixer to be

$$e_1 = A \cos \omega_s t$$

The mixer output components at the intermediate frequency are

$$e_{01} = \frac{AB}{2} \sin (\omega_s - \omega_{lo})t$$

$$e_{02} = \frac{AB}{2} \cos (\omega_s - \omega_{lo})t$$

The 90 degree if phase shift makes

$$e_{03} = \frac{AB}{2} \cos (\omega_s - \omega_{lo})t$$

when the signal is higher in frequency than the local oscillator. When the signal is lower in frequency,

$$e_{03} = - \frac{AB}{2} \cos (\omega_{lo} - \omega_s t)$$

When e_{02} and e_{03} are added at the if summation point, the lower signal frequency (image) is canceled. If they are subtracted, the higher signal frequency is canceled. The problems associated with the image phasing mixer are those of holding both gain and phase stable over a frequency band. Component requirements needed to implement the concept will be generated by the study.

2.2.2 Discrete and Hybrid Circuit Testing

The second major front-end design study topic will be an evaluation of key circuits performance for the active stages of the front end. The results of the literature search, theoretical front-end study, and fabrication investigation will influence the scope of this testing program. As currently envisoned, the following circuits will be evaluated:

a. Thin-film cascode rf amplifier.
b. Diode ring mixers.
c. Resistive FET ring mixers.
d. Square law FET mixer.
e. Image phasing mixer.

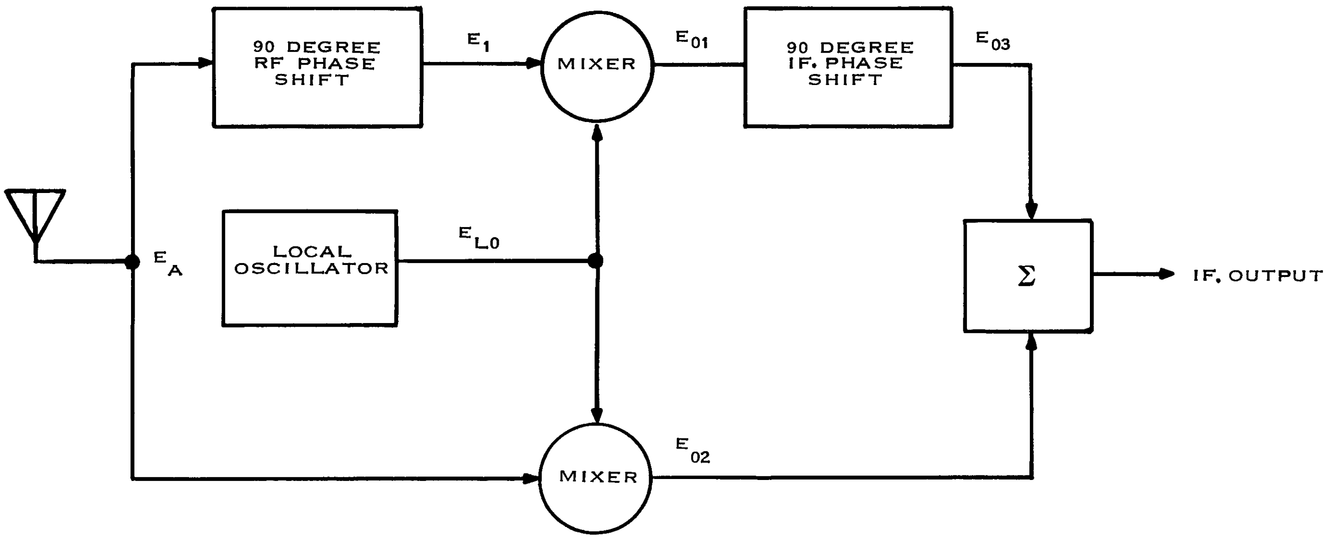


Figure 2-3. Image Phasing Mixer.

The parameters to be measured will include the following:

a. Input/output impedance.
b. Noise figure.
c. Gain or loss.
d. Cross modulation.
e. Intermodulation (2nd and 3rd order).
f. Spurious response up to 10th order.

The results of this testing will be combined with the theoretical study to arrive at feasible specification goals for a future microminiature uhf preselector development. Circuit deficiencies will be analyzed to give improved results.

2.3 FABRICATION METHODS

The present and future technologies in fabrication, metallurgical compatibility, and solid-state electronic phenomena will determine the ultimate shape and performance of the microminiature uhf tuner. This section will be concerned with an outline sketch of the currently known technologies, their form, capabilities, and limitations. These will serve as a guide to future study and material investigation. Figure 2-4 summarizes these technologies which are discussed in the following paragraphs.

2.3.1 Basic Processes

There are five methods today which are widely used to produce microminiature or integrated circuit capabilities.

The first of these methods is the one ultimately capable of producing the smallest, lowest cost, yet most reliable of circuits - the monolithic integrated circuit. The strict-monolithic circuit takes advantage of currently known solid-state phenomena to produce all the desired electronic functions within a single crystal of solid-state material, ~~that is,~~ for example silicon. The major limitation of this method is its frequency response. Because of the currently available techniques of isolating the separate circuit components within the same crystal, many

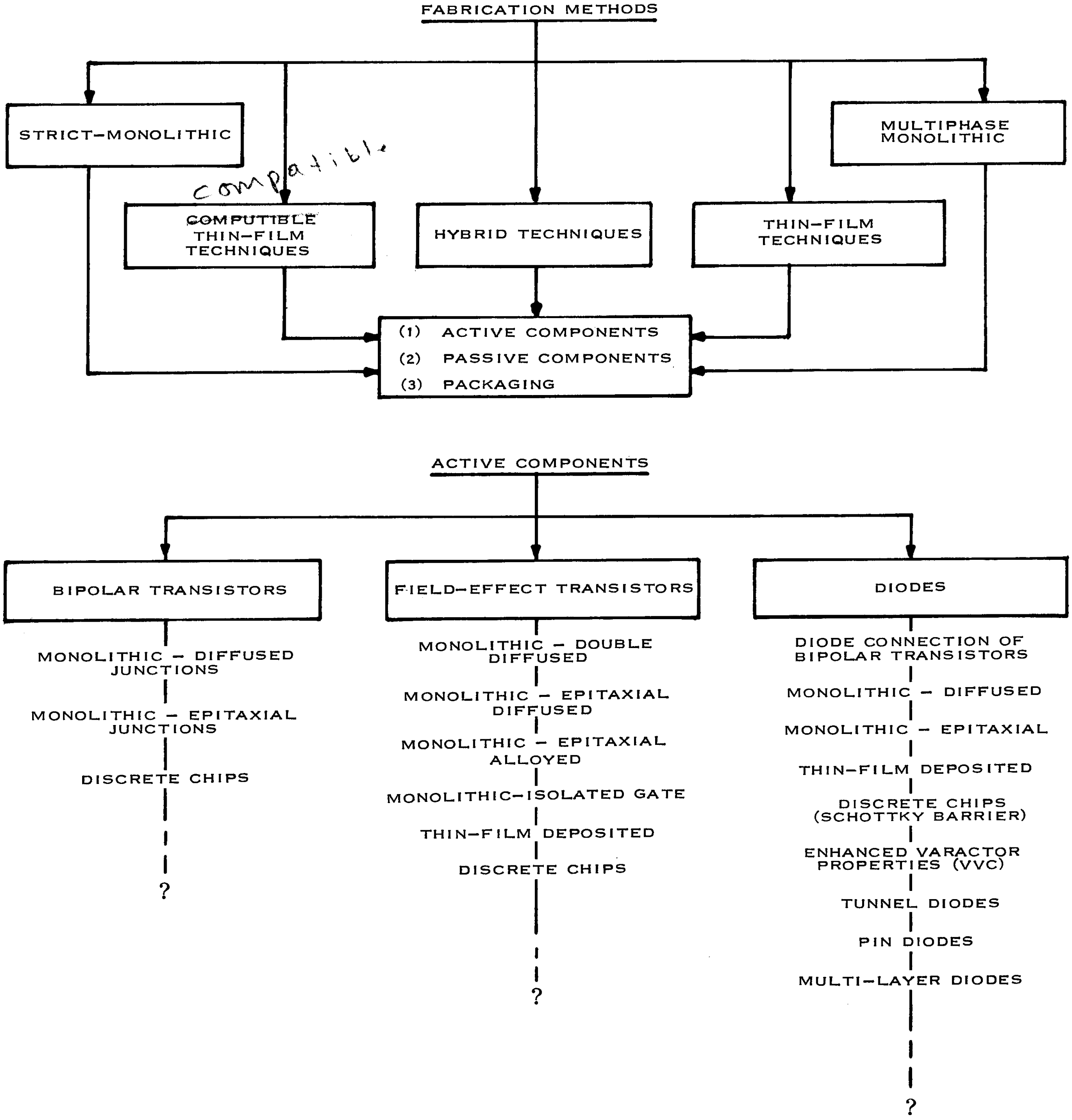


Figure 2-4. Fabrication Methods (Sheet 1 of 2).

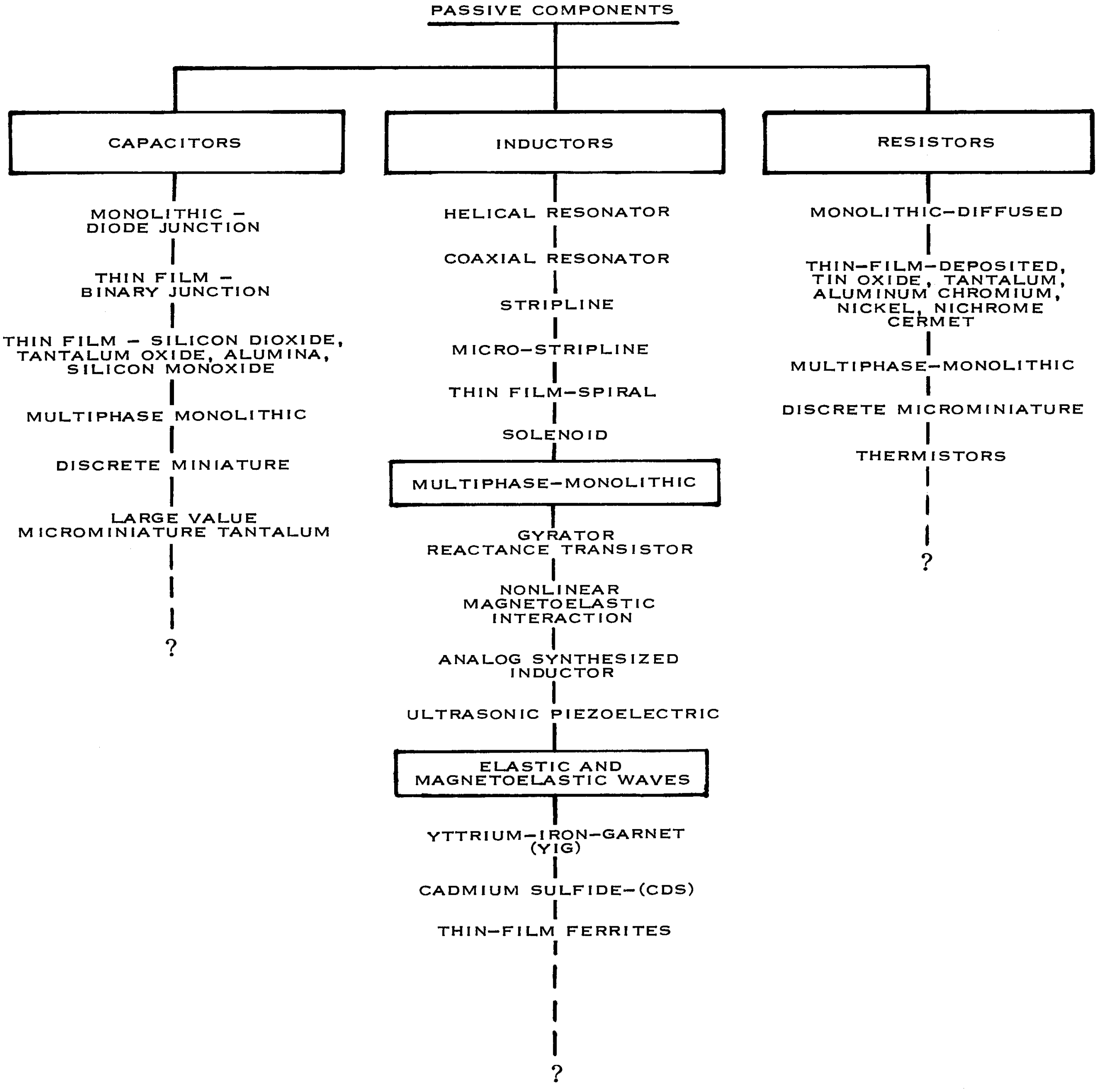

PASSIVE COMPONENTS
CAPACITORS
MONOLITHIC – DIODE JUNCTION
THIN FILM – BINARY JUNCTION
THIN FILM – SILICON DIOXIDE, TANTALUM OXIDE, ALUMINA, SILICON MONOXIDE
MULTIPHASE MONOLITHIC
DISCRETE MINIATURE
LARGE VALUE MICROMINIATURE TANTALUM
?
INDUCTORS
HELICAL RESONATOR
COAXIAL RESONATOR
STRIPLINE
MICRO-STRIPLINE
THIN FILM-SPIRAL
SOLENOID
MULTIPHASE-MONOLITHIC
GYRATOR REACTANCE TRANSISTOR
NONLINEAR MAGNETOELASTIC INTERACTION
ANALOG SYNTHESIZED INDUCTOR
ULTRASONIC PIEZOELECTRIC
ELASTIC AND MAGNETOELASTIC WAVES
YTTRIUM-IRON-GARNET (YIG)
CADMIUM SULFIDE-(CDS)
THIN-FILM FERRITES
?
RESISTORS
MONOLITHIC-DIFFUSED
THIN-FILM-DEPOSITED, TIN OXIDE, TANTALUM, ALUMINUM CHROMIUM, NICKEL, NICHROME CERMET
MULTIPHASE-MONOLITHIC
DISCRETE MICROMINIATURE
THERMISTORS
?

Figure 2-4. Fabrication Methods (Sheet 2 of 2).

undesirable parasitic elements are created. These parasitic elements "rob" the desired elements of their high frequency capabilities.

The second method is the use of compatible thin-film techniques. This method uses active devices produced in monolithic form and adds passive elements on top of the monolithic substrate using thin films. These passive elements produced by thin films usually have a higher operating frequency than their monolithic counterparts. This results in an integrated circuit usable at a higher frequency. To obtain this increased operating frequency, the designer must solve problems of higher cost, lower reliability, and worsened metallurgical compatibility when compared to the strict-monolithic.

The most widely used high-frequency (hf to microwave) integrated circuits are made using hybrid techniques. This method literally uses any combination of all the other methods in addition to discrete components. The price to pay for this superior frequency response is higher cost, lower reliability, and the largest size. These factors are the result of the need for bonding discrete elements to the substrate and interconnecting components by individual wire bonds. These operations are very often done by a human operator which further adds to the high cost and low reliability.

The fourth method could be described as a multiphase-polycrystalline technique or thin-film technique. At present, this method is usually limited to the deposition of thin-film passive elements on a substrate when the substrate has already been used in monolithic or hybrid construction. Research in the thin-film area has produced, and will produce in the future, active devices. An example is the thin-film FET which may be used in the future to produce complete thin-film integrated circuits.

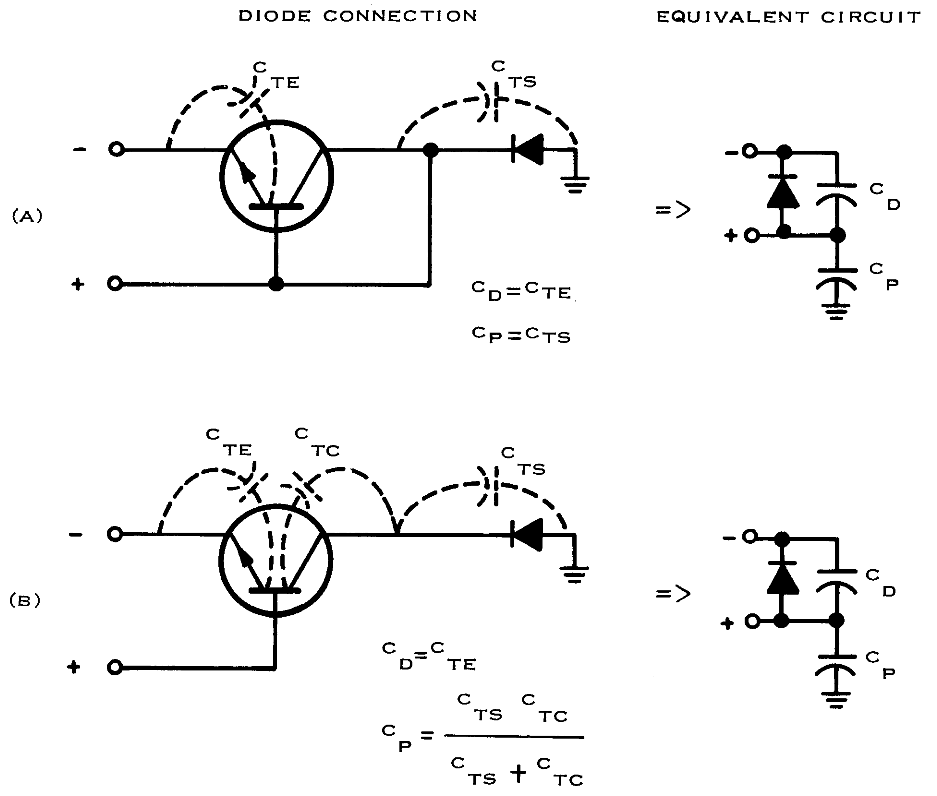
Finally, the method that could be the most promising for a uhf tuner is the multiphase monolithic technique. The multiphase-monolithic technique is very similar to the strict-monolithic except in the two important areas of isolation and frequency. The individual devices in the structure are separated by layers of silicon dioxide and polycrystalline silicon. The devices are diffused into the crystalline silicon which is isolated from the polycrystalline silicon base by a layer of silicon dioxide. This method of isolation eliminates many of the parasitic elements associated with the strict-monolithic circuit. This results in a much higher operating frequency. As always, the price to pay for the high-frequency operation is a very high fabrication cost. Still, it is recommended that considerable study time be given to this promising area of fabrication in hopes of producing a technology suitable to the uhf frequency range.

2.3.2 Active Components

The bipolar transistor is the basic element of active components in integrated circuits. Not only can it be used as a transistor but, by various connections, it can also be used, for example, as a diode, junction capacitor, or voltage-controlled capacitor. The bipolar transistor fabrication in integrated circuits is a highly developed technology with literally thousands of literature sources available. Among the most common form of bipolar transistors are monolithic-diffused junctions, monolithic-epitaxial, and discrete chips manufactured by various technologies.

Field-effect transistors are offering increased possibilities for use in integrated circuits. Some advantages are radiation immunity and the thin-film compatibility of deposited FET's. More fabrication possibilities are available with FET's than with bipolar transistors; a good example is compatible thin-film FET's. FET's are available in various technologies including monolithic double-diffused, monolithic epitaxial-alloyed, multiphase-monolithic insulated gate, thin-film deposition, and discrete chips of various technologies. The present limitations of FET's are high cost and lower frequency response; however, these limitations will disappear as improved technology becomes available. The study should take a close look at thin-film FET's in particular as a compatible construction technique at uhf.

Integrated circuit diodes usually depend upon the type of bipolar transistor fabrication employed, because many IC diodes are made by connecting a bipolar transistor for diode operation. These monolithic diodes usually have two or more parasitic capacities as shown in figure 2-5 for two possible connections. The effect of these parasitic elements is to lower the frequency response and, for parasitic transistor action (not shown), to increase reverse conductance. The properties of the diode junction as shown in the table will vary with the bipolar fabrication making the selection of diode and transistor characteristics



(C)

CHARACTERISTIC	(A) $V_{CB} = 0$	(B) $I_C = 0$
BREAK DOWN VOLTAGE–VOLTS	7	7
STORAGE TIME NSEC	9	56
FORWARD VOLTAGE–VOLTS	0.85	0.96
PARASITIC TRANSISTOR BETA	0	3
C_D PF TYPICAL	0.5	0.5
C_P PF TYPICAL	2.9	1.2

Figure 2-5. Equivalent Circuits and Typical Properties of Two Bipolar Transistors Connected as Diodes in Monolithic Integrated Circuits.

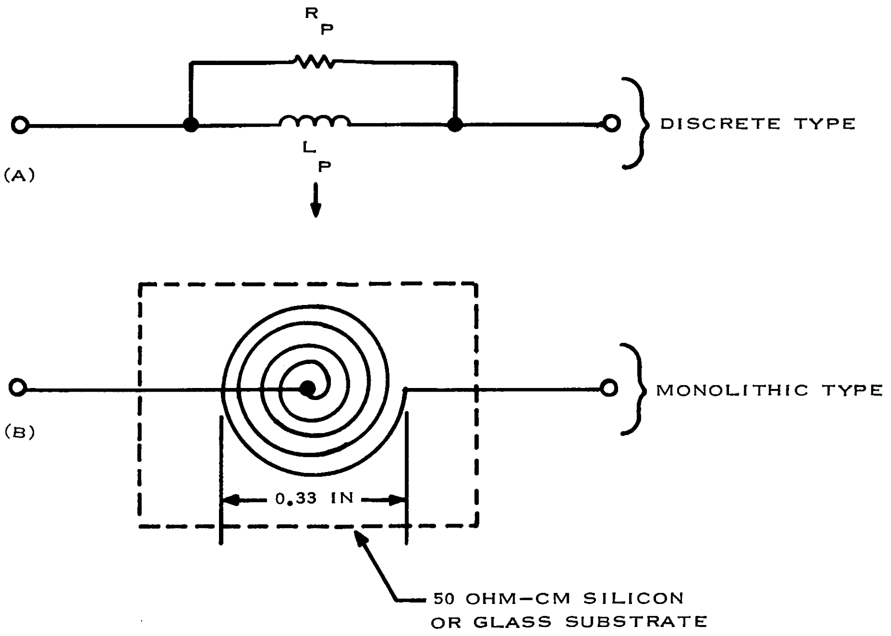
highly interdependent. To avoid this problem, but with additional cost, other methods of diode fabrication are used, including monolithic-diffused, monolithic-epitaxial, thin-film deposited, multiphase-monolithic, and for hybrid circuits discrete chips.

The use of varied fabrication methods allows deliberate enhancement of specific diode properties as in Schottky Barrier, varactor, tunnel, pin, and multilayer diodes. Recombination impurity doping is also employed to minimize charge storage and thus increase frequency response. Again the usual trend is for cost to increase as frequency increases. The study should determine the diode of highest frequency response that is still compatible with the goal of monolithic construction. Multiphase monolithic techniques could be the starting point for study in this area.

2.3.3 Passive Components

Passive components to be discussed are capacitors, inductors, and resistors. The most troublesome component to produce in integrated form is the inductor. Any future development studies should spend considerable time in this area. The possibilities of both discrete and integrated inductors should be covered to gain a good understanding of the problems and present solutions. Discrete inductors currently available include the inductive reactance associated with helical resonators, coaxial resonators, strip line and microstrip line resonators, and the familiar solenoid coil.

Thin-film inductors are currently represented by the thin-film spiral. This inductor is shown in figure 2-6 along with a chart showing the very low Q of inductors fabricated in this manner. The future study should devise ways to increase this low Q.



(C) COMPARISON OF THE INDUCTOR Q FOR A THIN-FILM, 20-TURN, FLAT SPIRAL ON SILICON AND ON GLASS SUBSTRATES.

FREQUENCY, MHZ	50 OHM-CM SILICON		GLASS	
	INDUCTANCE MICROHENRIES	Q	INDUCTANCE MICROHENRIES	Q
20	2.26	4.9	2.18	36.2
40	2.57	3.4	2.33	49.4
60	3.20	1.7	2.82	47.1
80	4.42	0.89	3.91	35.1

Figure 2-6. Thin-Film Flat Spiral Inductor.

A monolithic realization of a uhf inductor is a goal of the future. Much work is currently being done to solve this problem but, to date, very little hardware is available. Two methods to be studied in this area are standard low frequency techniques and exotic solid-state phenomena. Well known circuit theory is used to synthesize active inductors with gyrators using R, C, and transistors. The reactance transistor can produce an inductance in a manner similar to the reactance tube. Some solid-state phenomena utilize elastic, magneto-elastic, piezoelectric, and ultrasonic properties of materials to produce an inductance. Materials to study for these phenomena should include yttrium-iron-garnet (YIG), cadmium sulfide (CdS) and various thin-film ferrites. The limited amount of breadboarding called for in the study could include one or two of the above methods to show the practical problems involved.

Resistors for integrated circuits have been extensively developed and the goal of the study will be to select the resistor fabrication compatible with the chosen fabrication method. Some methods to consider are: monolithic-diffused, thin-film deposited (several materials available), multiphase monolithic, and available discrete microminiature units. Special consideration should be given to temperature dependent resistors (thermistors) for use in the compensation of tuning and bias voltages. The monolithic-diffused and thin-film resistors have parasitic elements which must be reduced or eliminated for uhf applications. Figures 2-7 and 2-8 illustrate the problems associated with obtaining good resistors for uhf frequency application. Again, a good area to look into might be the multiphase monolithic technique.

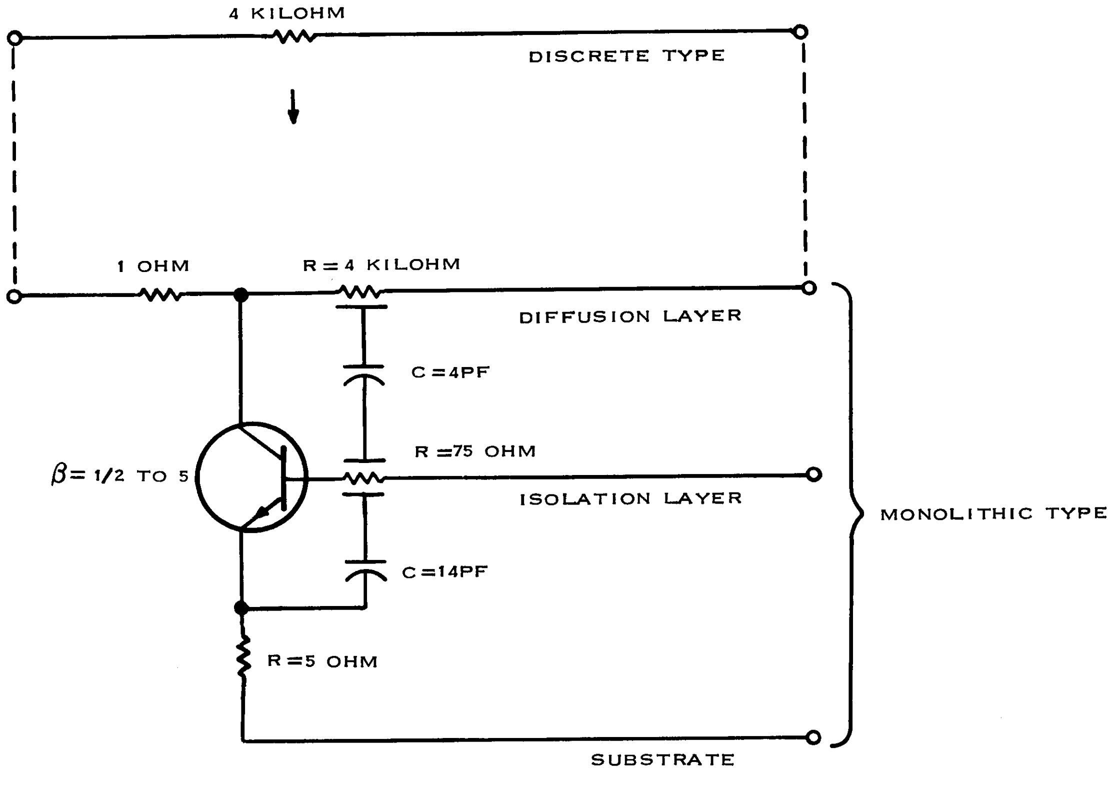


Figure 2-7. Simplified Equivalent Circuit of a Typical Monolithic Diffused Resistor Showing Parasitic Elements and Valves.

Values

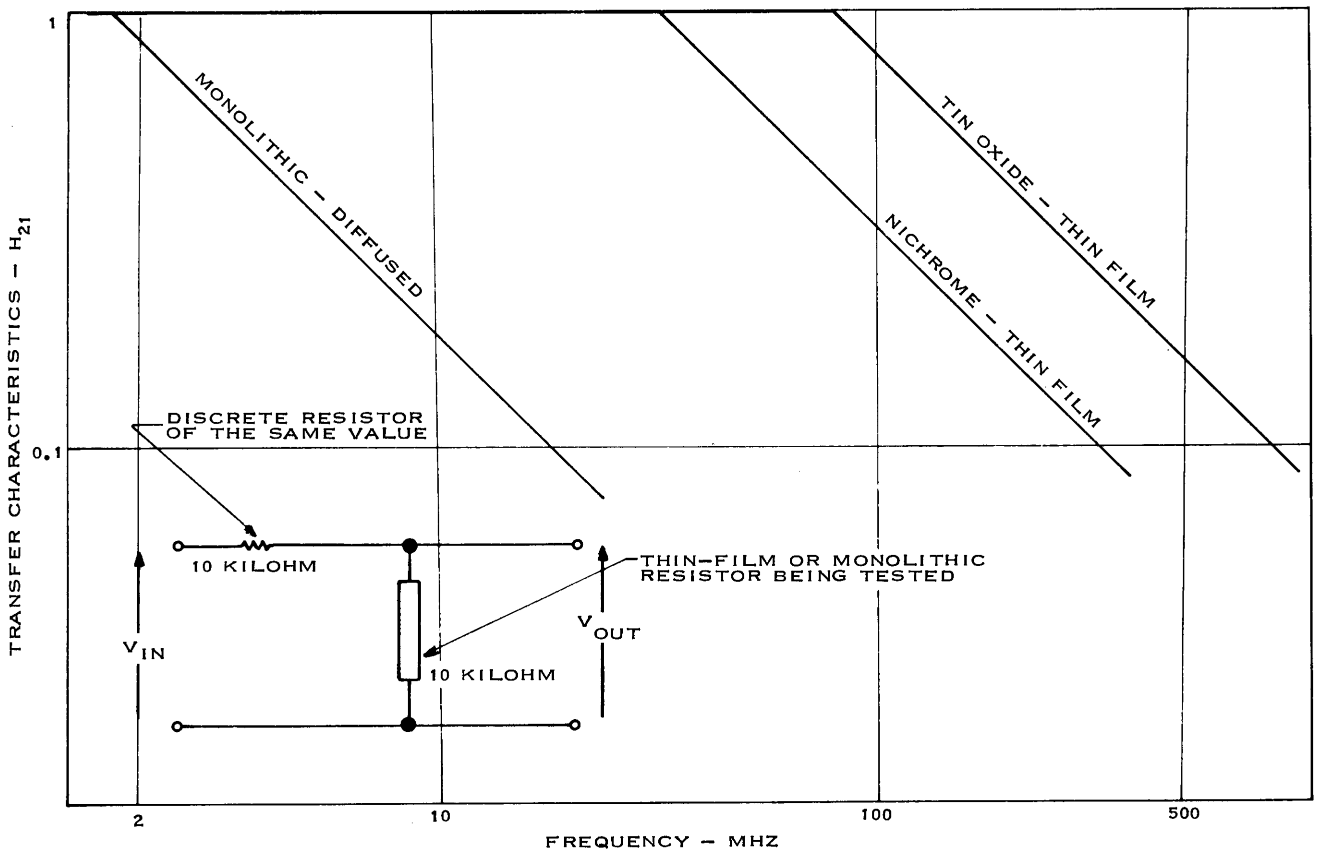


Figure 2-8. Calculated Frequency Dependence of a 10 Kilohm Resistor Fabricated Using Well Known Thin-Film and Diffusion Techniques.

Still another important area in the study should be high Q capacitors for use at uhf. Table 2-1 shows the typical characteristics for monolithic junction capacitors. The Q provided by a junction capacitor is low when uhf filter requirements are considered. Junction capacitors are generally back-biased diodes so that all the fabrication techniques applicable to diodes also apply to the junction capacitor. Other areas to consider are: thin-film binary junction, thin-film dielectric, multiphase monolithic, discrete miniature, and microminiature tantalum for large capacity values. Voltage-controlled diodes for use as electrically tuned capacitors will be important and a good possibility for electrically tuned filters.

2.3.4 Packaging

A consideration of the packaging of the complete uhf tuner must be conducted at the same time as the other fabrication methods. The method of packaging will affect electrical and mechanical performance and dictates the integration of various technologies when using the hybrid technique.

Table 2-1. Capacitor Characteristics for Hybrid and Monolithic Junction Capacitors.

CAPACITOR CHARACTERISTICS	HYBRID	MONOLITHIC
Maximum capacitance/area, pF/mil^2	1.0	0.2
Maximum area, mil^2	10^4	2×10^3
Maximum capacity, pF	10^4	400
Breakdown voltage, volts	5 - 50	5 or 20
Q	10 - 50	1 - 10
Voltage coefficient	$C \quad kv^{-1/2}$	$C = kv^{-1/2}$
Tolerance	±10%	±20%

An example of this consideration is internal and external rfi shielding, such as decoupling internal circuits and emi compatibility. Interfacing considerations of rf input, injection input, if output, tuning voltage input, and dc power input affect the integration of the uhf tuner into a complete receiver. Thermal expansion compatibility and shape factor must be considered for every design. This area should be investigated for each proposed fabrication technique. Additionally, bonding methods will affect packaging and frequency response. Established methods such as wedge and ball thermocompression bonding should be compared to newer methods such as beam-lead bonding.

Two excellent examples of Collins thin-film and hybrid technology are shown in figures 2-9 and 2-10. Figure 2-9 is of an rf amplifier-mixer at 300 MHz, and figure 2-10 is a 210 MHz injection oscillator. The package without leads is typically 1.000 inch long, 0.850 inch wide, and 0.150 inch thick although a variation of package shapes is available.

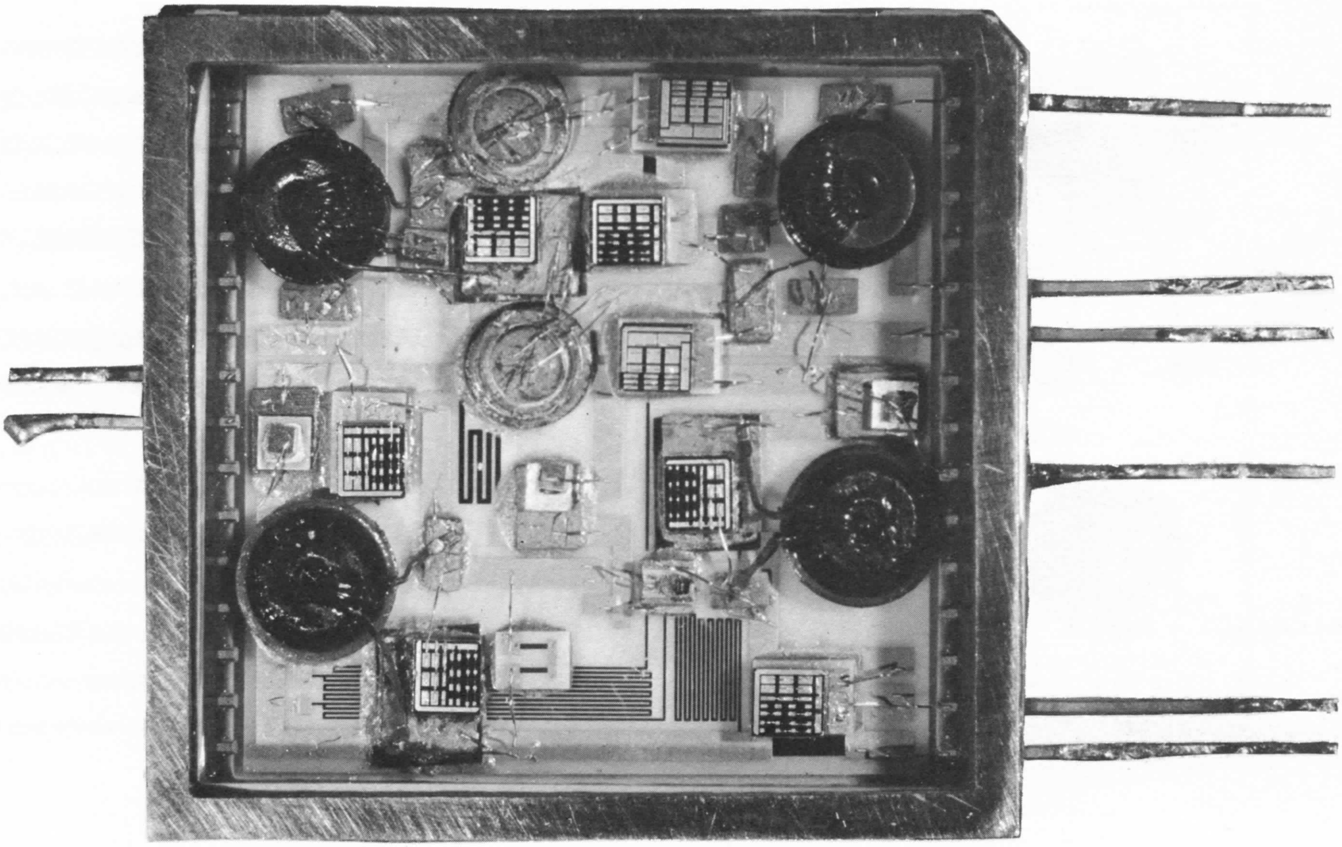


Figure 2-9. UHF RF Amplifier-Mixer Using Thin-Film Hybrid Construction.

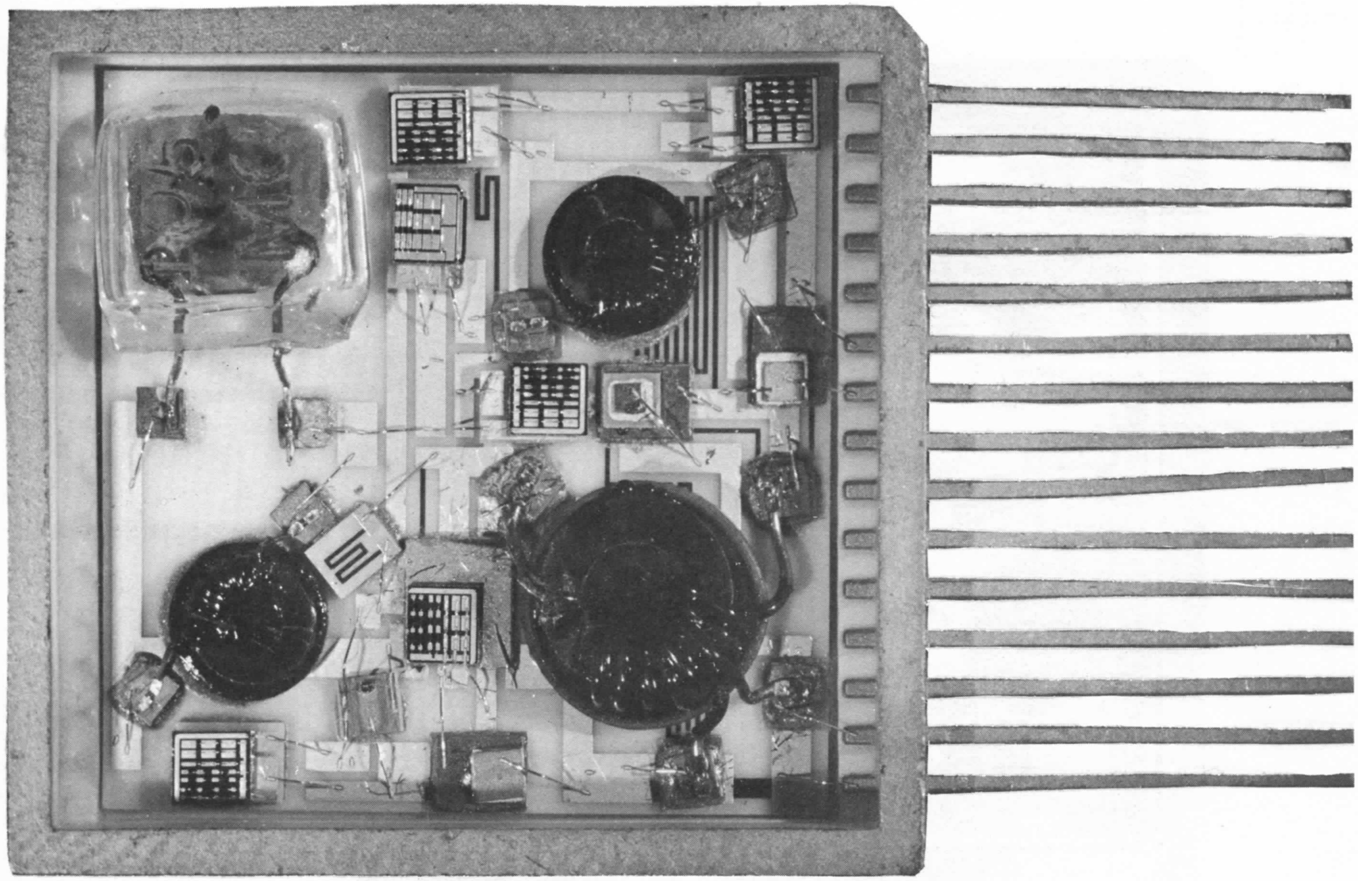


Figure 2-10. UHF Injection Oscillator With Crystal Control on Thin-Film Substrate.

2.4 TUNING METHODS

The means of attaining rf selectivity in a microminiature tuner requires careful study to produce acceptable image, spurious response and sensitivity trade-offs. A summary of tuning methods is shown in figure 2-11; the following paragraphs describe these methods in more detail.

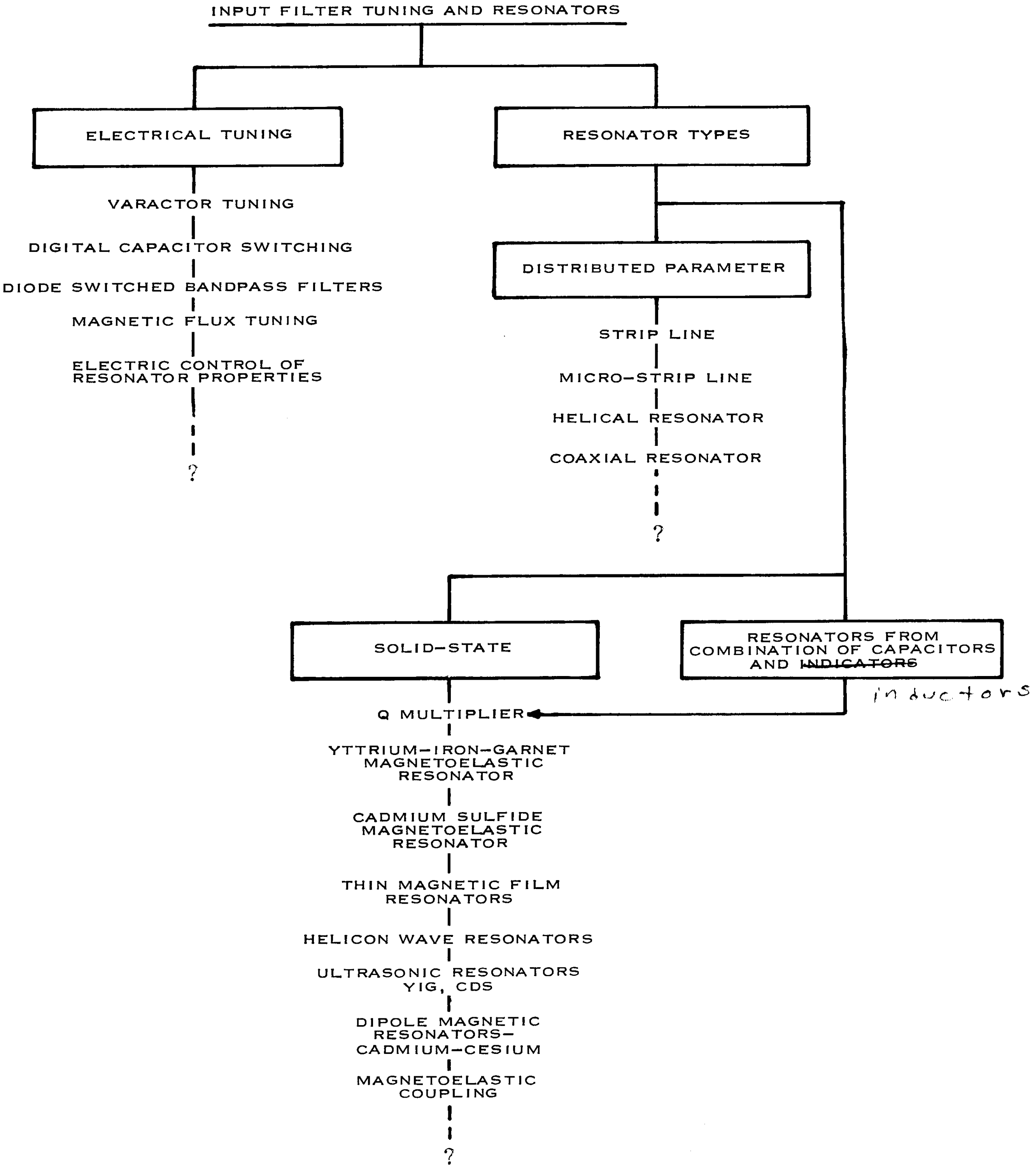

INPUT FILTER TUNING AND RESONATORS
ELECTRICAL TUNING
VARACTOR TUNING
DIGITAL CAPACITOR SWITCHING
DIODE SWITCHED BANDPASS FILTERS
MAGNETIC FLUX TUNING
ELECTRIC CONTROL OF RESONATOR PROPERTIES
?
RESONATOR TYPES
DISTRIBUTED PARAMETER
STRIP LINE
MICRO-STRIP LINE
HELICAL RESONATOR
COAXIAL RESONATOR
?
SOLID-STATE
RESONATORS FROM COMBINATION OF CAPACITORS AND ~~INDICATORS~~
inductors
Q MULTIPLIER
YTTRIUM-IRON-GARNET MAGNETOELASTIC RESONATOR
CADMIUM SULFIDE MAGNETOELASTIC RESONATOR
THIN MAGNETIC FILM RESONATORS
HELICON WAVE RESONATORS
ULTRASONIC RESONATORS YIG, CDS
DIPOLE MAGNETIC RESONATORS-CADMIUM-CESIUM
MAGNETOELASTIC COUPLING
?

Figure 2-11. Input Filter Tuning and Resonator Design and Fabrication Considerations.

2.4.1 Electrical Tuning

Any consideration of tuning methods and resonators will be influenced by the need for high resonator Q in the input filter. Selectivity improves and filter loss decreases as the resonator Q increases. This then means that the trade-off factors of selectivity, resonator Q, and filter loss will have to be considered in unison with tuning methods. The method of electrical tuning will depend on the type of resonator selected, but, in general, tuning methods involve the control of capacity and magnetic flux.

Varactor-tuned resonators are a common solution for electrical tuning and can be readily used in hybrid construction. The main performance problems with varactor tuning are large signal distortion and filter detuning caused by the signal interfering with the varactor dc tuning voltage. The study should look into the problem of fabrication of high Q varactors for monolithic or multiphase monolithic circuits.

Digital capacitor switching with pin diodes should also be investigated. This method could involve the switching, with pin diodes, of fixed diffused junction or thin-film capacitors. One problem is the large array of diodes and capacitors needed to tune many channels. Another problem is the low Q associated with the diode capacitor combination. The study should propose solutions to these problems.

In a manner similar to diode switching, it may be possible to switch complete bandpass filters for each segment of the desired band. This would allow the use of high Q resonators employing, for example, piezoelectric effects. Again, the problem is the large number of elements needed to cover a wide band.

Magnetic flux tuning involves the electrical control of the magnetic flux in solid-state resonators. This area offers the greatest future possibilities for integrated circuit uhf tuners and should be a major area of concentration.

Any electrical control of resonator properties will provide electrical tuning, and this study should provide new ideas for this control.

Breadboarding of the most promising electrical tuning method should be attempted if time permits, because this will probably be the most sensitive circuit area.

2.4.2 Resonator Types

Possible resonators for the input filter can be classified into three general areas: discrete distributed-parameter resonators, solid-state resonators, and LC resonators composed of the capacitors and inductors previously discussed. Solid-state resonators offer the greatest microminiature capabilities but very little hardware has been produced due to technology limitations. The LC resonators suffer the low Q limitations discussed in preceding paragraphs of this section. The most widely used, but also the largest, resonators for uhf are the distributed parameter resonators.

The basic theoretical limitations of Q as a function of resonator volume are well developed in the literature. Figure 2-12 shows the dependence of maximum available resonator Q as a function of resonator volume for helical and coaxial resonators at 315 MHz. This volume versus Q trade-off is inescapable when designing distributed parameter resonators. For a given uhf quarter-wave resonator frequency and desired Q, the helical resonator requires the least volume of commonly used discrete resonators. The basic limitation will carry over into any uhf resonator design. Other distributed parameter resonators include strip-line and

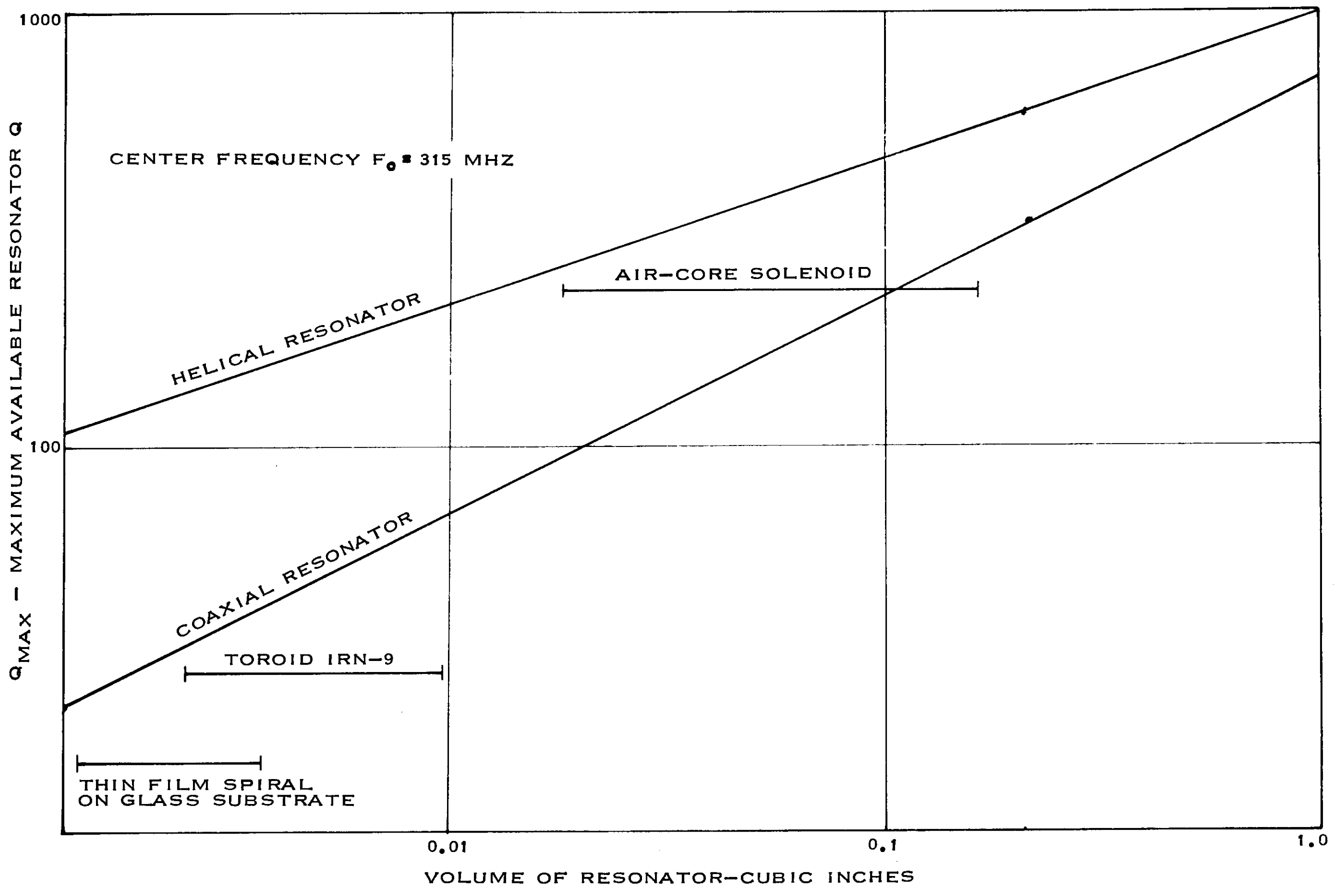


Figure 2-12. Comparisons of Maximum Available Q for Five Different Inductance or Resonator Techniques in the UHF Band (Maximum Theoretical Q for a Given Constructional Volume).

microstrip-line techniques. The low Q and large area of strip-line techniques will set a lower limit on the size of a given filter design.

As previously stated, the greatest possibility for microminiature high Q resonators is in the solid-state area. The special resonance effects of certain solid-state material can be utilized to produce filters at uhf. The future study will have to probe the literature for any presently available hardware for solid-state resonators. Possibly, the study should propose a future promising area in solid-state resonators where concentrated development could produce useful hardware. Some areas for future study should include: piezoelectric uhf resonators, yttrium-iron-garnet (YIG) and cadmium sulfide (CdS) magnetoelastic resonators, ultrasonic resonators using materials such as YIG and CdS and magnetoelastic coupling phenomena. Areas which deserve special comment due to small size or availability are thin magnetic film resonators, dipole magnetic resonance (cesium), and Helicon wave resonators.

2.5 NEW COMPONENT REQUIREMENTS

To overcome the disadvantages of previously discussed components, some new element requirements can be proposed. The future study should examine these component requirements and expand on the realization of the most promising ones. The following is a tabular listing of desirable future components:

a. A solid-state uhf mixer capable of higher dynamic range and lower required injection power.
b. High Q inductors in monolithic and thin-film forms.
c. Tuning varactors with high tuning voltages to minimize signal induced voltage swing and fabricated in monolithic form.
d. Diode and FET switches with low turn-on resistance and high on-off ratio.
e. High Q monolithic and thin-film capacitors.
f. Parasitic free monolithic and thin-film resistors.
g. Solid-state high Q resonators to improve the rf input filter selectivity.
h. Incremented tuning in fixed capacitors for use in integrated circuits.
i. One-way solid-state isolators to prevent injection power from reaching the antenna.
j. Schottky barrier diodes in monolithic or multiphase monolithic form.
k. Monolithic crystal filter for uhf.
l. 90 degree hybrid couplers for uhf integrated circuits.

2.6 CIRCUIT CONSIDERATIONS

The study for a uhf microminiature tuner should include a section on circuit techniques. This section would be concerned with the practical problems associated with the layout, measurement, and configuration of the uhf circuits applicable to microminiaturization. All the practical problems encountered in the design of discrete uhf circuits should be transformed to apply to microminiature circuits and studies, along with the practical problems unique to microminiature techniques. The following is a listing of a few of the topics that could be included:

a. The circuit layout of first models must consider techniques of probe coupling to provide the best possible measurement capabilities.
b. Investigation of common-ground and parasitic feedback problems.
c. Component placement for minimum lead inductance and component-to-component coupling.
d. Techniques to minimize stray lead-to-lead capacities in package pins and connectors.
e. The types of discrete components currently available for hybrid circuits.
f. Development of alternate configurations of the same circuit functions so that the configuration with the least parasitic elements can be chosen.
g. Incorporation of useful additional circuits, such as burnout and overload protection.
h. Incorporation of circuit compensation for temperature extremes.

2.7 ENVIRONMENTAL CONSIDERATIONS

Temperature, radiation damage, rfi shielding, vibration, and shock effects on a microminiature uhf tuner should be considered when choosing the final methods of construction. Temperature, for example, will have varying effects on such quantities as gain, conversion loss, Q, power dissipation, thermoexpansion compatibility, and tuning voltage control. Radiation effects as may be encountered in space will be minimized if majority conduction effects are utilized exclusively. Effects of emi, vibration, and shock will depend on construction and packaging methods. Other environment considerations unique to microminiature designs will become apparent as the study progresses.

2.8 TRADE-OFF ANALYSIS

Some of the trade-off existing in the design of a uhf front end have been described in connection with the outline of theoretical and circuit measurement studies. Using the results of the study, the literature search and the fabrication/tuning method investigation, trade-off charts will be prepared. These charts will relate basic design approaches to performance, cost, size, power demand, reliability, and practicality of monolithic integration. An example of the technical trade-off between the image rejection of a front end and the intermediate frequency is shown in figure 2-13. This is representative of the performance of an electric tuner at the low end of the uhf band. A corollary to figure 2-13 would be a comparison of the number of spurious responses versus intermediate frequency. For a given set of performance specifications, the trade-off analysis will allow determination of the best approach to a microminiature uhf front end.

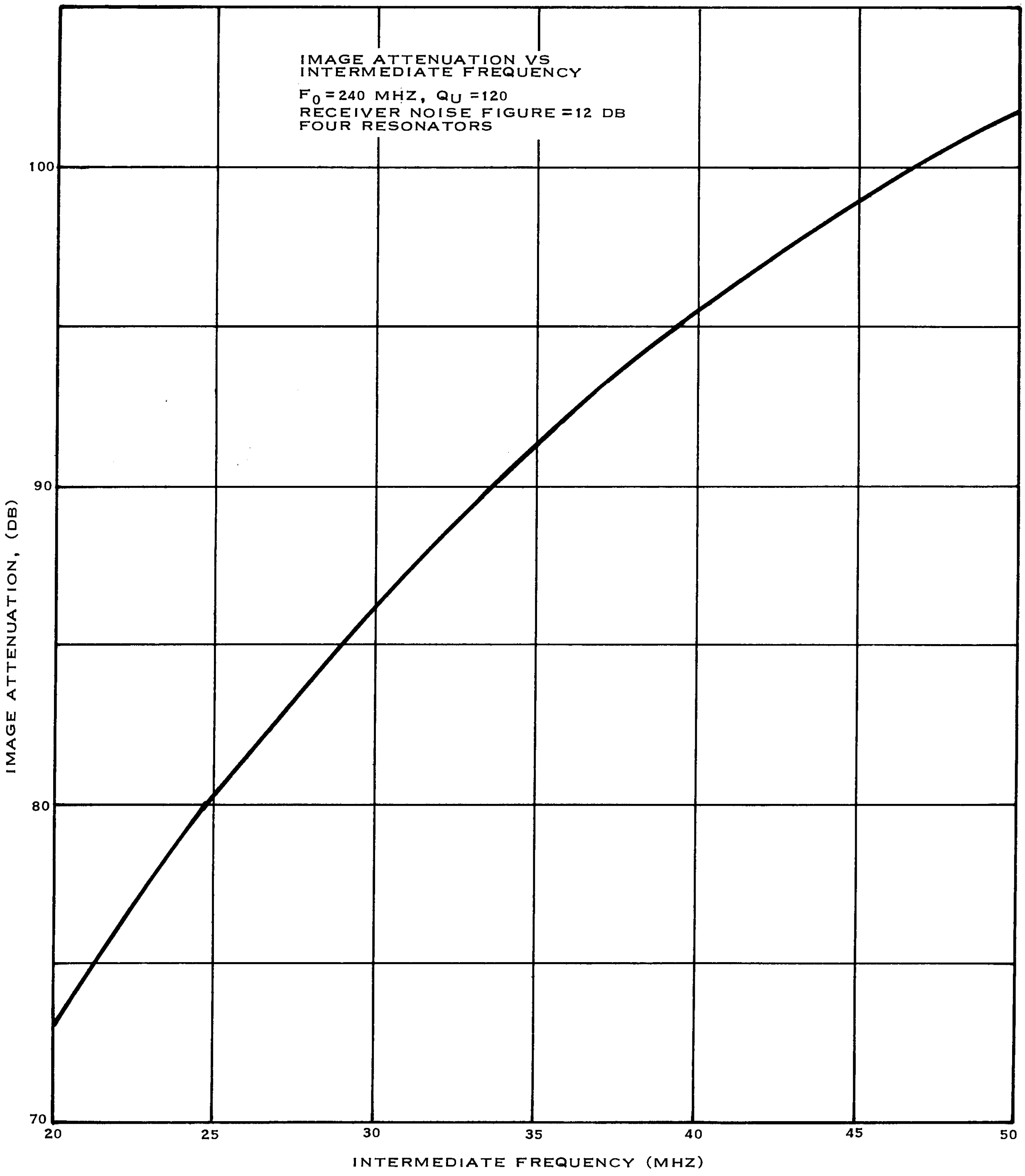


Figure 2-13. Image Attenuation Versus Intermediate Frequency.

BLANK PAGE

Project Time Schedule

The following list defines the schedule of major events that will occur during the course of the study. The milestone times shown are referenced to the contract date.

MILESTONE	TIME	
Literature search complete	3 weeks ARO	
Design principle review	1 month ARO	
Submit milestone/cost plan	1 month ARO	
Tuning method analysis	3 months ARO	
Active device evaluation	3 months ARO	
Packaging study complete	4 months ARO	
Interim engineering report	4 months ARO	
Hybrid circuit testing complete	5 months ARO	
Advanced component specification	5 months ARO	
Trade-off analysis complete	6 months ARO	
Complete final report draft	6 months ARO	
Close project	6 months ARO	Dec-3
Submit final report	7 months ARO	Jan-3

Additionally, reports of progress against the program requirements of type I milestone/cost report are to be submitted monthly during the course of the study.

BLANK PAGE

Personnel Assignments

The following list identifies the primary personnel (Cedar Rapids Region, Collins Radio Company) to be assigned to the program and gives a short resume of the person's experience. The indicated percentages show the expected utilization factor.

a. Project Engineer: (95 Percent) R. W. Hanson

Mr. Hanson received a BS degree in electrical engineering from the University of Wisconsin in 1959.

Following his graduation, Mr. Hanson joined Collins Radio Company, Cedar Rapids Division. His initial assignment was if design work on the SRC-16 and ARC-80 hf communications equipment. As a member of an advanced tuner development group, he has performed extensive studies in the area of low noise, low distortion, receiver front end design in the hf, vhf, and uhf frequency ranges.

Mr. Hanson participated in the design of the rf and if receiver circuits of the 618M-2 and 51RV-2 vhf communication and navigation equipment. He was project engineer in the development of the high performance receiver front end used in the ARC-138 UHF Transceiver. Currently, Mr. Hanson is engaged in a study of linear integrated circuits for rf and if applications.

He is a member of the honorary engineering society, Eta Kappa Nu.

b. Assistant Project Engineer: (95 Percent) S. F. Russell

Mr. Russell received his BSEE from Montana State University in 1966; and is doing graduate work at Iowa State University.

Mr. Russell has been responsible for design and development of the self-test and injection oscillators for Collins 621A-5 Transponder and of uhf preamplifiers for TACSATCOM - including low noise amplifiers and highly selective helical resonator filters. He has performed basic investigations of field effect transistors for receiver front ends and theoretical investigation of vhf balanced ring modulators and frequency multipliers. His work in receiver evaluation techniques includes noise factor and intermodulation distortion.

Mr. Russell is concentrating in passive and active network synthesis, integrated circuit technology, and transistor physics in his graduate work at Iowa State University.

c. Project Supervisor: (10 Percent) D. B. Hallock

Mr. Hallock attended Worcester Polytechnic Institute. He received a BS degree in electrical engineering in 1953 and an MS degree in electrical engineering in 1954.

Mr. Hallock joined Collins Radio Company following graduation and since has been active in the design of receiving and transmitting equipment in the hf through uhf frequency ranges. At uhf, he has conducted basic investigations into high performance receiving tuner design and has applied modern filter synthesis techniques to low-loss tunable filters in the 225 to 400 MHz range. He has also been responsible for a wide-band uhf power generator in connection with the AN/PRC-66 development. His present position is group head of the Tuner Design Group.

Mr. Hallock is a member of the honorary engineering society, Eta Kappa Nu, and holds two patents.

Additional personnel in the thin-film process and silicon diffusion areas will be employed during the course of the study in a consulting and advisory status. The laboratory technicians required for circuit implementation are available from the laboratory services pool.

Facilities

This section describes Collins facilities that are relevant to the proposed design study, including Research and Development selected manufacturing facilities.

Since incorporation in 1933, Collins Radio Company has been engaged in development and production of advanced communications and navigation systems and specialized electronic equipment. The Company's capabilities have continually grown to keep pace with the ever increasing equipment complexity and the expanding need for more reliability, and for smaller and more dense packaging. Today the Company is an international organization drawing on the talents of over 22,000 employees and using advanced facilities occupying 3,924,000 square feet of floor space. Principal laboratories and factories are located in Cedar Rapids, Iowa; Dallas, Texas; and Santa Ana and Newport Beach, California. Collins Radio Company of Canada Ltd, Toronto, Ontario is a wholly owned subsidiary.

5.1 RESEARCH AND DEVELOPMENT FACILITIES

Collins Radio Company maintains research and development facilities (having a combined floor space of 727,000 square feet) in Cedar Rapids, Iowa; Dallas, Texas; and Newport Beach, California.

5.1.1 Laboratories

5.1.1.1 Radio Engineering

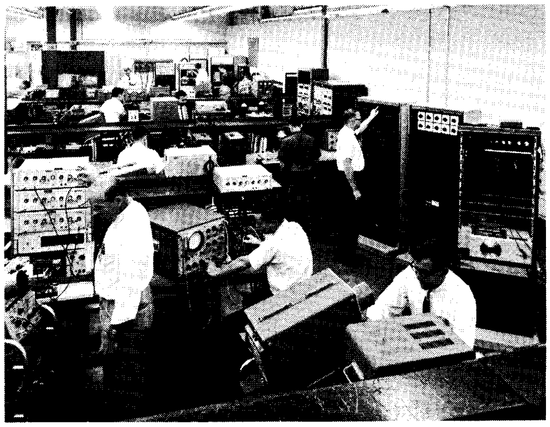


Figure 5-1. Engineering Lab.

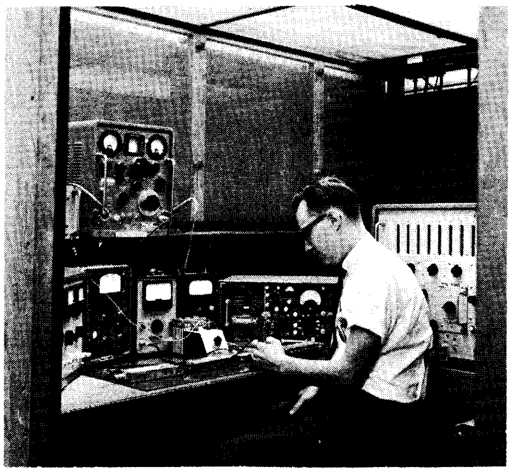


Figure 5-2. Screen Room.

Radio development labs are located adjacent to each engineering office area providing engineers with readily accessible work space. (See figure 5-1.) Small machine shops containing basic tools are located in each area for use by the lab technicians and engineers. A larger and more completely equipped machine shop is provided in a central location for their use. Equipment under test is isolated from interfering signals by screen rooms (figure 5-2) located throughout the laboratories. A complete array of test equipment is available upon request from a centralized test equipment pool.

Technicians assigned to development lab work are selected on the basis of their experience and training. Each technician must pass a formal examination before being classified in this grade. Work performed in the lab is assigned on a project basis and is closely directed by the cognizant engineer. The competence of the technicians assures the engineer of more time for the design aspects of his project.

5.1.1.2 White Rooms

Special rooms (figure 5-3) are provided for use in the development of aircraft instruments, gyros, and similar critical devices. These White Rooms are air-conditioned separately from the adjacent areas and are maintained at a constant temperature and humidity. Dust and lint levels are carefully controlled. Employees working in these areas wear lint-free White-Room clothing.

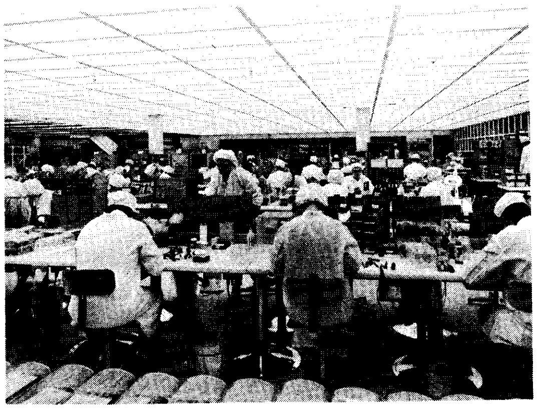


Figure 5-3. White Room.

5.1.2 Measurements and Standards

The Measurements and Standards Laboratory maintains the fundamental values of voltage, resistance, capacitance, and inductance with standards certified by the National Bureau of Standards. (See figures 5-4 and 5-5.) Our calibration program provides over a thousand secondary and working standards maintained with the required accuracy. More than 8,000 hours a year are spent in keeping these standards calibrated. In addition to being used in maintaining the test equipment, the standards facility is available to all engineers requiring precise measurements in such areas as rf, uhf, and vhf power, frequency to 12.4 GHz, FM deviation, impedance and vswr, dielectric constant, attenuation, temperature, and hf and vhf transistor and diode parameters.

5.1.3 Model Shop

Metal and plastic fabricated parts for engineering prototypes are constructed in a large model shop administered by Manufacturing. The model shop employs 134 craftsmen and

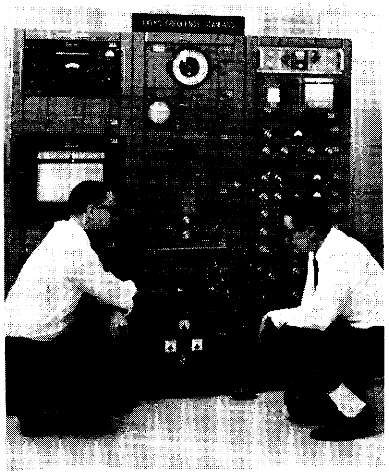


Figure 5-4. Collins 100 kHz Frequency Standard.

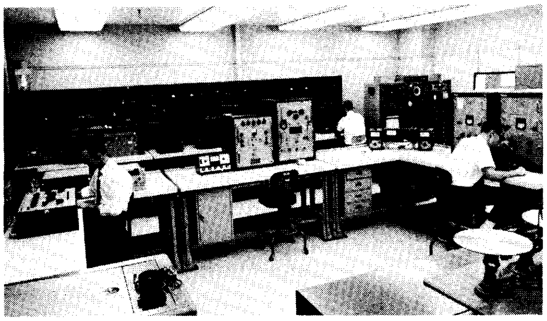


Figure 5-5. Section of Engineering Standards Laboratory Showing Some of the Equipment Available for Special Measurement Problems.

occupies 14,000 square feet. The shop provides small-quantity building of metal-fabricated or mechanical components on an expeditious schedule and fabricates complex mechanical devices from the engineers' sketches or rough drawings. Milling machines, jig bores, engine lathes, gear hobber, gear shaper, band saws, drill presses, brakes, punch presses, shears, spot welders, and arc welders are available within these facilities. Effective use is made of chemical fabrication techniques and other functional areas such as plating, plastics, and painting in the production of engineering models.

5.1.4 Chemistry and Plastics

Chemical research and analysis plays an important part in many Company activities. Chemistry Laboratory facilities are used for failure analysis tests, for receiving inspection, and for new product and process evaluations. Chemists manning the Chemical Research Laboratory conduct studies in organic materials composition, physical testing, advanced failure analysis, and production process evaluation and procedure preparation. Special problems are assigned to this area for solution. Some of the devices used in this laboratory include an infrared spectrophotometer, a tensile and compression tester, and two gas chromatographs, one with a flame ionization attachment. Lab facilities for normal wet chemistry are also provided. Apart from the main lab is the Chemical Analysis Laboratory where studies are continually being conducted in process and bath analysis, corrosion problems, plating thicknesses, metallurgy, and both inorganic and organic material inspection. The chemists and technicians have a prime responsibility for verifying the quality of hardware used in all company projects. A Unitron metallograph augments the facilities provided in this lab.

5.2 RELATED MANUFACTURING FACILITIES

5.2.1 Microelectronics

We currently have microelectronics production facilities in Cedar Rapids, Dallas, Newport Beach, and Toronto, Canada, with a 3-year expansion program under way. Table 5-1 illustrates our total floor space and production rate in circuits per day at the present time. In 1967 Cedar Rapids and Dallas microelectronics facilities were moved into new buildings with areas specifically designed for more efficient operation and higher production rates.

Table 5-1. Floor Space and Production Rate.

PRESENT	
FLOOR SPACE	PRODUCTION RATE
37,000 sq ft	750 circuits per day

Each site has a complete thin-film fabrication capability with equipment necessary to perform sputtering, vapor deposition, photoresist, etching, anodizing, resistor and capacitor testing, substrate cutting, component mounting and bonding, packaging, and testing. Each site uses common processes and reports to a common director, resulting in compatibility of circuits manufactured in different areas.

A semiconductor capability is being developed at Collins Semiconductor Division directed at the development and manufacture of large scale circuit arrays produced by MOS and bipolar device technologies. Digital circuit arrays constructed of MOS devices are being offered first.

5.2.1.1 Thin-Film Hybrid Circuits

Thin-film hybrid circuits are integrated circuits that use various combinations of thin-film resistors and capacitors, discrete transistor and diode chips, and monolithic integrated circuits combined on a ceramic substrate and interconnected with bonded wires.

We have complete facilities for fabrication of thin-film devices. Many standard functional elements are now being developed and fabricated. These include digital logic arrays, counter circuits, analog amplifiers with the feedback networks enclosed in the thin-film package, and many other combinations for performing digital and analog computations.

The hybrid begins as a ceramic plate upon which are laid very thin films of metal to form resistors, capacitors, and their interconnections. A thin-film resistor may be a tiny metal strip only a few thousandths of an inch wide and as long as necessary to deliver the needed resistance. A zigzag pattern is sometimes used to fit a high value resistor on the ceramic base.

A thin film of insulating material with a thin film of metal above and below is a capacitor. By varying the surface area and the thickness of the insulating material, capacitor values can be adjusted to precise specifications.

Changing a substrate coated with thin metal films into a complete thin-film integrated circuit involves photographic masks and etching. A large scale drawing of the circuits desired is photographically reduced to create a mask the actual size of the circuits. The metal-coated substrate is covered with a light sensitive emulsion by a process called photoresist, and exposed to light through the mask. Portions of the thin film beneath clear areas of the mask are then etched away, leaving a circuit pattern.

Several thin-film layers are deposited one on top of the other by this procedure to create resistors and capacitors. The last step is deposition of a layer of conductive metal using the photoresist-mask-etch procedure to form the interconnections between circuit elements and to provide the means to connect them with the outside world.

Although several metals can be used, tantalum and some of its compounds offer the advantages of flexibility, high quality, and toughness.

To exactly adjust resistors, they may also be anodized. By close monitoring, circuits of thin-film resistors and capacitors can be manufactured to extremely close tolerances for precise performance. In a continual research and development program, we have refined thin-film technology to a dependable production technique. Typical thin-film hybrid circuits are illustrated in figure 5-6. Description and photos of hybrid thin-film manufacturing operations are shown in figure 5-7.

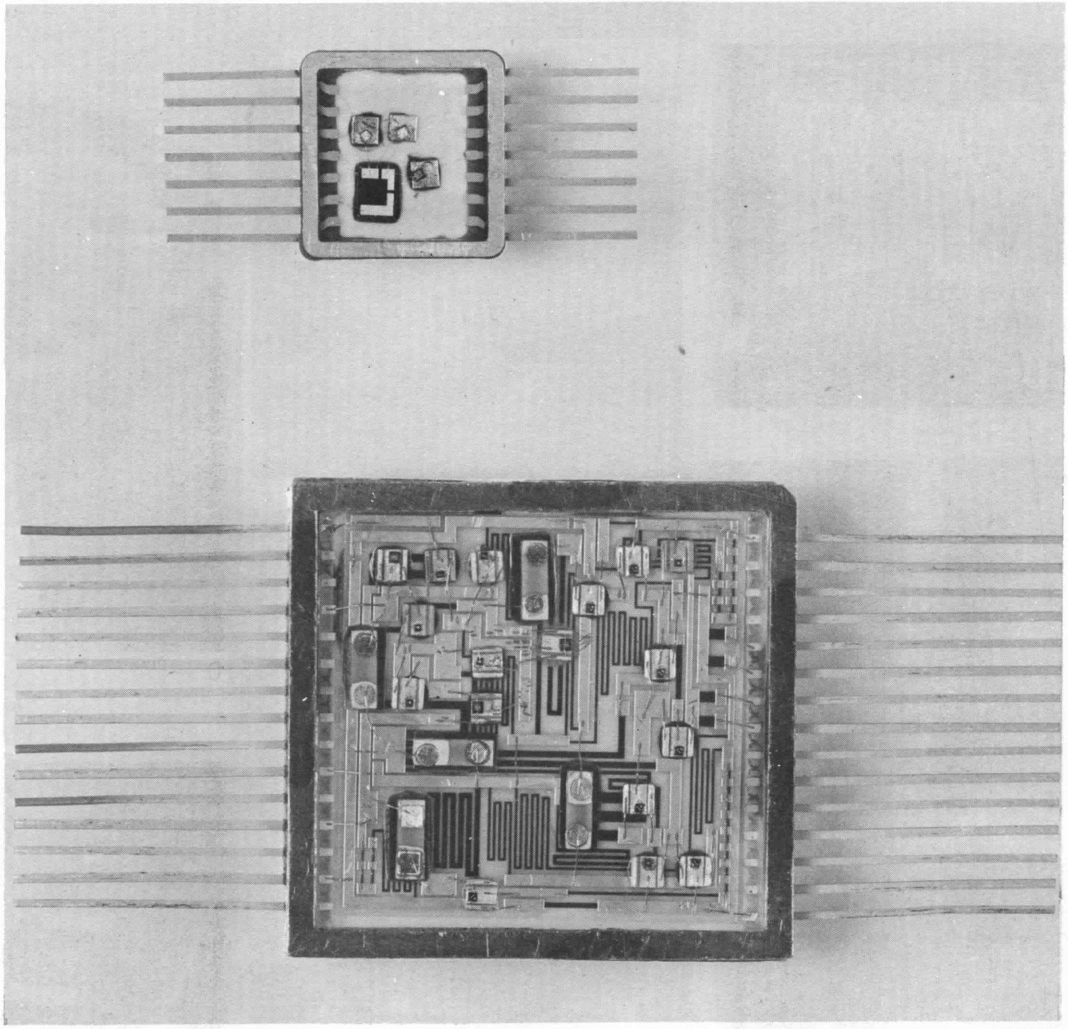
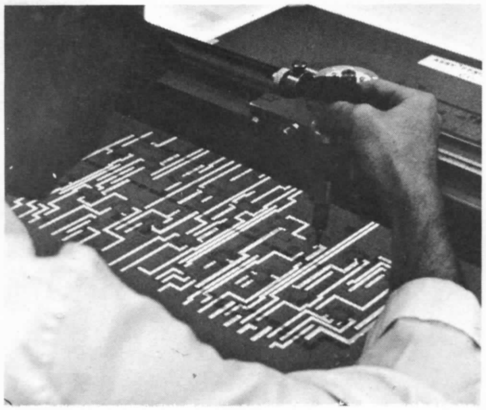
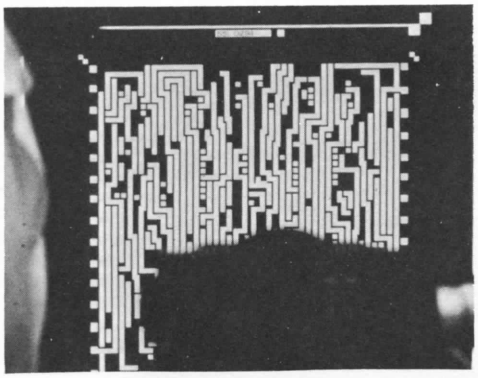
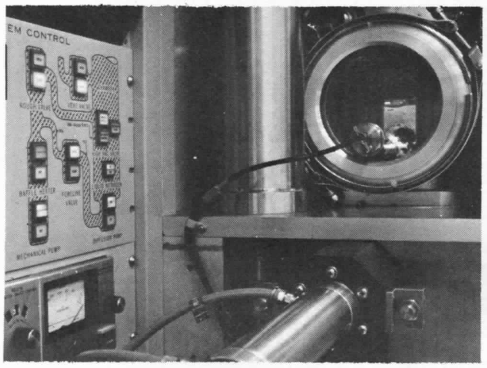


Figure 5-6. Typical Thin-Film Hybrid Circuits.

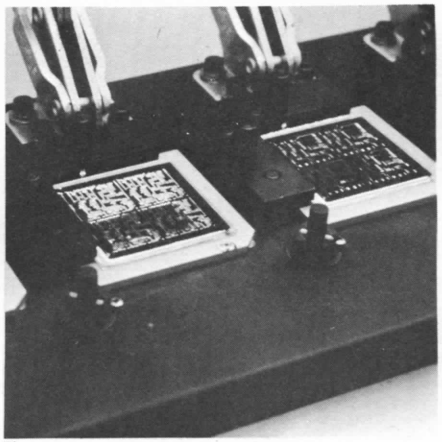

1

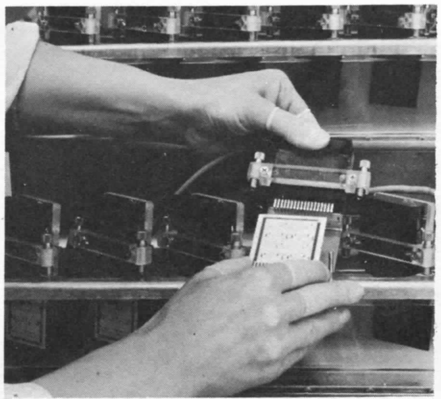

2

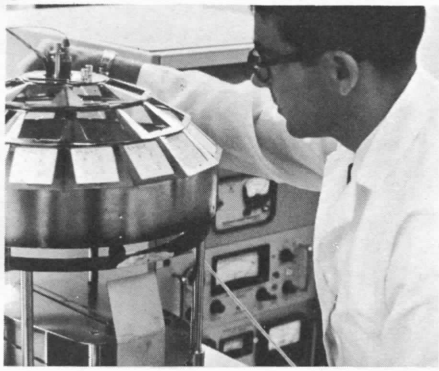


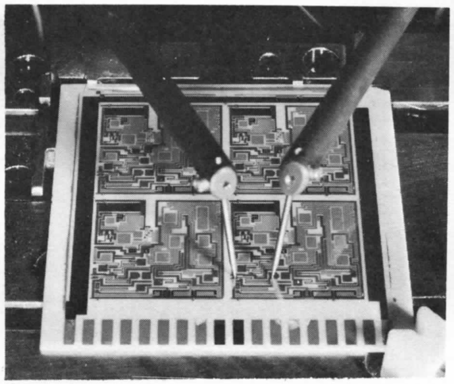
3

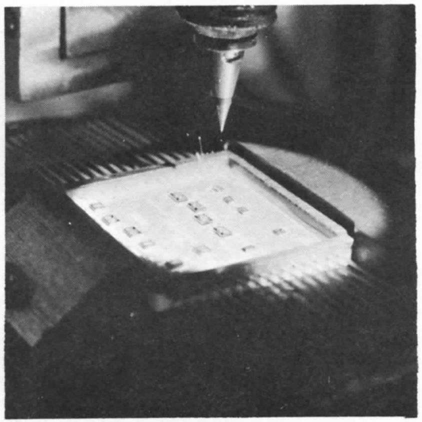
4

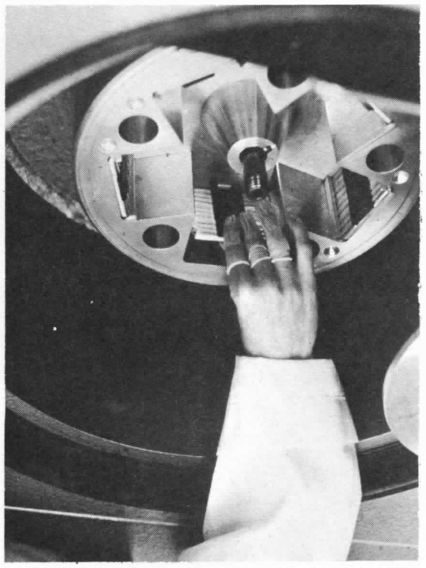

5


6


7


8


9


10

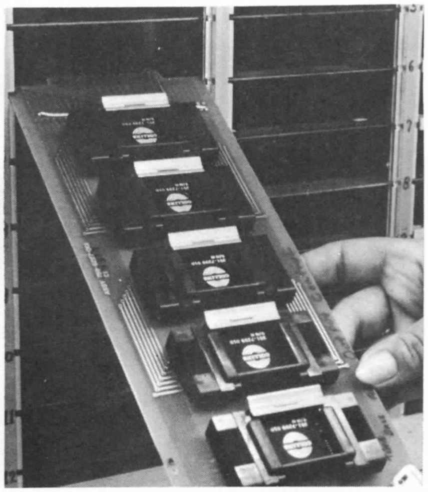

11

Figure 5-7. Hybrid Thin-Film Manufacturing Operations (Sheet 1 of 2).

After the desired circuit function is translated into a schematic diagram, layouts of the composite drawings of each circuit layer are made on gridded Mylar. From these layouts, "cut-and-peel" artwork is prepared on a coordinatograph table employing a micrometer-positional scribe producing lines accurately to 0.001 of an inch.

1

Capacitor, conductor, and resistor patterns of the layouts are photographed at a reduction of 20:1 onto a 2-inch glass film plate containing four separate and identical circuit patterns (step-and-repeat process). The glass film plate is then mounted on a phototool frame.

2

Deposition by an automated in-line vacuum sputtering station is made of the first layer of tantalum on a 2-inch square, glazed ceramic substrate. This tantalum layer is then thermally oxidized in a tube furnace to protect the glaze from various etchants used in subsequent operations. The oxidized substrate is returned to the sputtering machine for deposition of the capacitor tantalum layer.

3

The capacitor tantalum now has a layer of photoresist applied by a centrifugal spinner. This machine dispenses a metered amount of photoresist on the substrate and spins at a precise speed for a predetermined period, resulting in a controlled photoresist thickness.

4

The sensitized substrate is exposed to ultra-violet light through the photomasks prepared in step 2, advanced to a second spinner for application of photoresist developer, and chemically etched to form the tantalum capacitor areas. Resist stripping and cleaning follow.

5

Capacitor tantalum is anodically oxidized in an electrolyte. The tantalum oxide serves as a capacitor dielectric.

6

Addition of the resistor pattern begins by return of the substrate to the sputtering station for a layer of resistor tantalum. The substrate is loaded into an aluminum evaporation station for a layer of aluminum for the conductor pattern. This is followed by a coating of photoresist, exposure of the conductor pattern, development, and etch in the same manner as was the capacitor, and then a second coating of photoresist, exposure of the resistor pattern, development, and etch.

7

The substrate - which now contains the capacitor, conductor, and resistor patterns - is tested automatically at a probe station controlled by computer program. The probes are sequenced through the pattern, testing the resistor and capacitor parameters. Following these tests, the thin-film deposition portion of the process is completed, and the 2- by 2-inch substrate is divided into four 0.75- by 0.75-inch quadrants of single units.

8

Discrete devices (transistors, diodes and integrated circuits) are individually probe tested and attached to the 0.75- by 0.75-inch substrate. The semiconductor devices are either eutectically bonded to gold-plated tabs which are then mounted with adhesive to the substrate, or are attached directly to the substrate. The electrical connections are made by either thermal-compression wire-bonding or ultrasonic bonding.

9

After the wire-bonding operation and trimming of external leads, the thin-film unit is sealed and subjected to a centrifugal test of 20,000 g.

10

The packaged unit is subjected to leak test, thermal shock, and temperature burn-in with power applied, followed by final electrical testing. The unit is now packaged for shipment.

11

Figure 5-7. Hybrid Thin-Film Manufacturing Operations (Sheet 2 of 2).

5.2.1.2 Micromodules

Micromodules are analog operational and signal conditioning circuits utilizing discrete components such as transistors, diodes, capacitors, and resistors, plus monolithic integrated circuits and thin-film hybrid circuits. The modules are constructed in cordwood fashion with welded internal connections and then encapsulated in epoxy. They have external leads that are solderable for easy connection to other circuits. The micromodule construction technique is illustrated in figure 5-8.

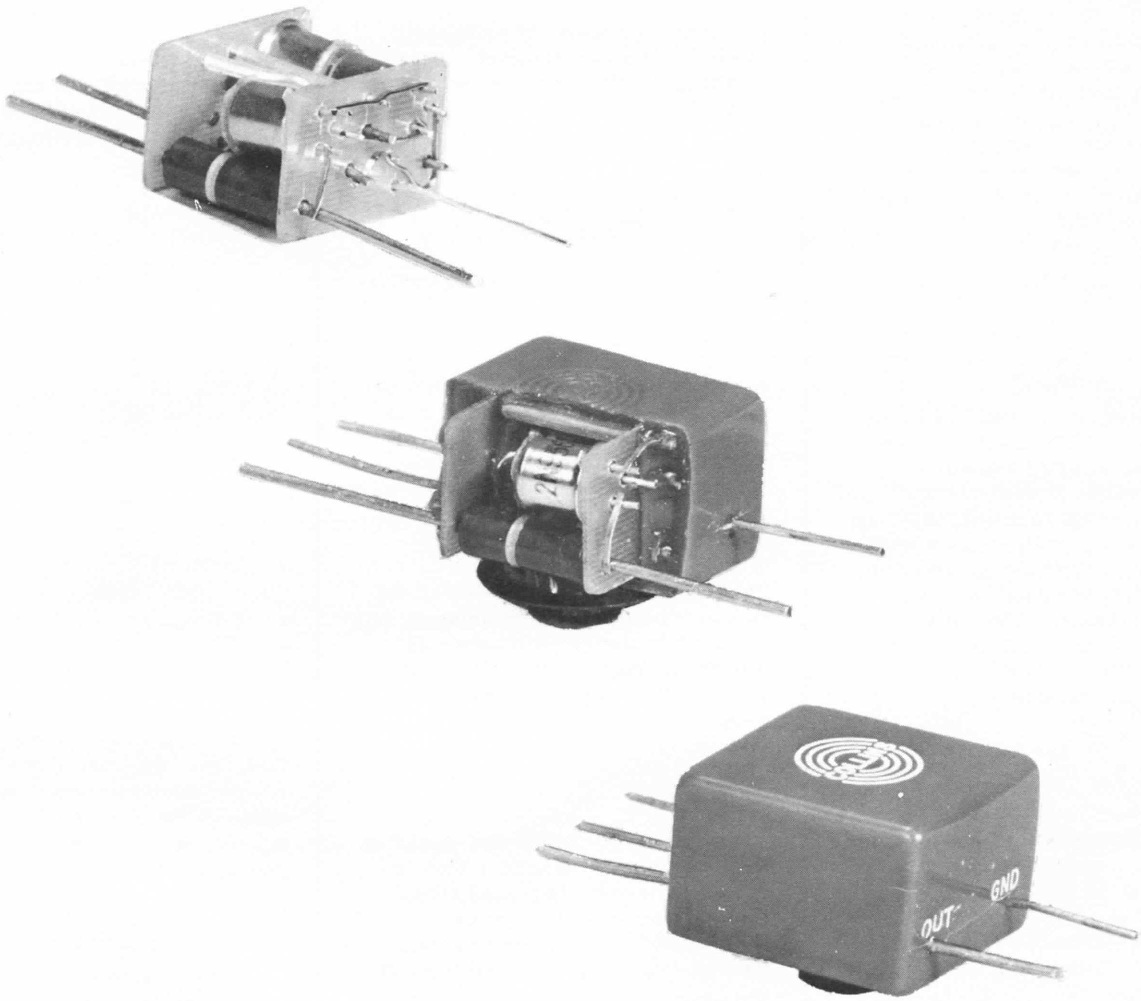


Figure 5-8. Micromodule Construction.

Each micromodule is designed to perform a specific functional task under strict specification control. The completed module is treated as a component defined by a component specification utilizing the same part number for identification. Component specifications, lists of material release, component approval procedures, standard layout techniques, mounting board patterns, welding procedures, testing techniques, and mold sizes have been fully developed for manufacturing these modules.

The modules have been accepted widely by engineering and production to simplify design, layout, assembly, test, and maintenance of equipment. Overall equipment costs have been lowered by use of the modules.

Among the important factors for the increasing use of these modules are their functional nature, tight specifications, size, reliability, and relatively low cost due to efficiency of production resulting from standardized design.

The modules are being manufactured at a 4,000-per-week rate for more than 200 different functions.

Among the applications are systems for flight control, distance measuring, altitude measurement, and power supplies.

Figure 5-9 illustrates the major steps involved in the micromodule production cycle. The family of standard micromodule sizes is illustrated in figure 5-10.

5.2.1.3 Metal Oxide Semiconductors (MOS)

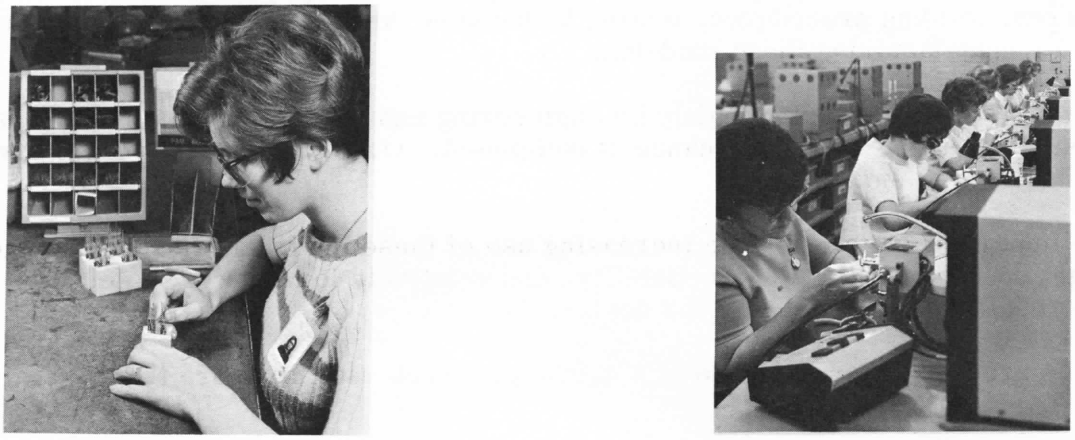
The Collins MOS Department has been fabricating MOS circuit arrays since March 1968. Devices which have been designed and are being routinely fabricated include an 8-bit, plus-sign, analog-to-digital converter and a 5-bit, digital multiplexer.

The 8-bit, plus-sign, a/d converter utilizes two MOS arrays that contain all of the necessary registers, timing, control logic, and resistor ladder switches. These two MOS packages, with the addition of a discrete or thin-film ladder, an IC comparator, and a reference power supply, perform the analog-to-digital conversion function. The same two MOS arrays can be reconnected through external leads to perform a digital-to-analog function.

The 5-bit digital multiplexer consists of one MOS array. This multiplexer utilizes 305 MOS devices which perform the function of 95 logic circuits. This array (see figure 5-11) is typical of a number of digital logic circuits that are now in design or being fabricated. During the first part of 1969, approximately 25 designs will be implemented as part of the Collins program to develop the next generation of product line equipment utilizing MOS large scale integrated devices.

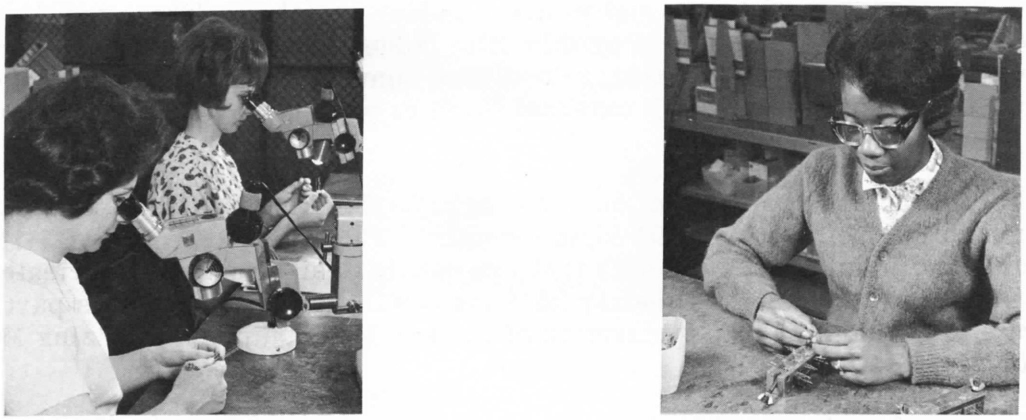
Optimum utilization of medium and large scale integrated (MSI, LSI) circuit arrays requires that each array be designed to accomplish its unique logic function. Production is geared to make a variety of parts efficiently, even where the quantity of each part is small. Semiconductor production is a controlled fabrication facility with a defined process. The unique characteristics of each IC are controlled through photomasking.

The production facility is laid out to utilize a number of work centers through which the work flows during fabrication. Those work centers that require a high degree of control have been



a. Loading components between Mylar films.

b. Welding the interconnects between component leads.



c. Inspecting under a microscope for weld quality.

d. Inserting in mold for encapsulation.

Figure 5-9. Micromodule Production.

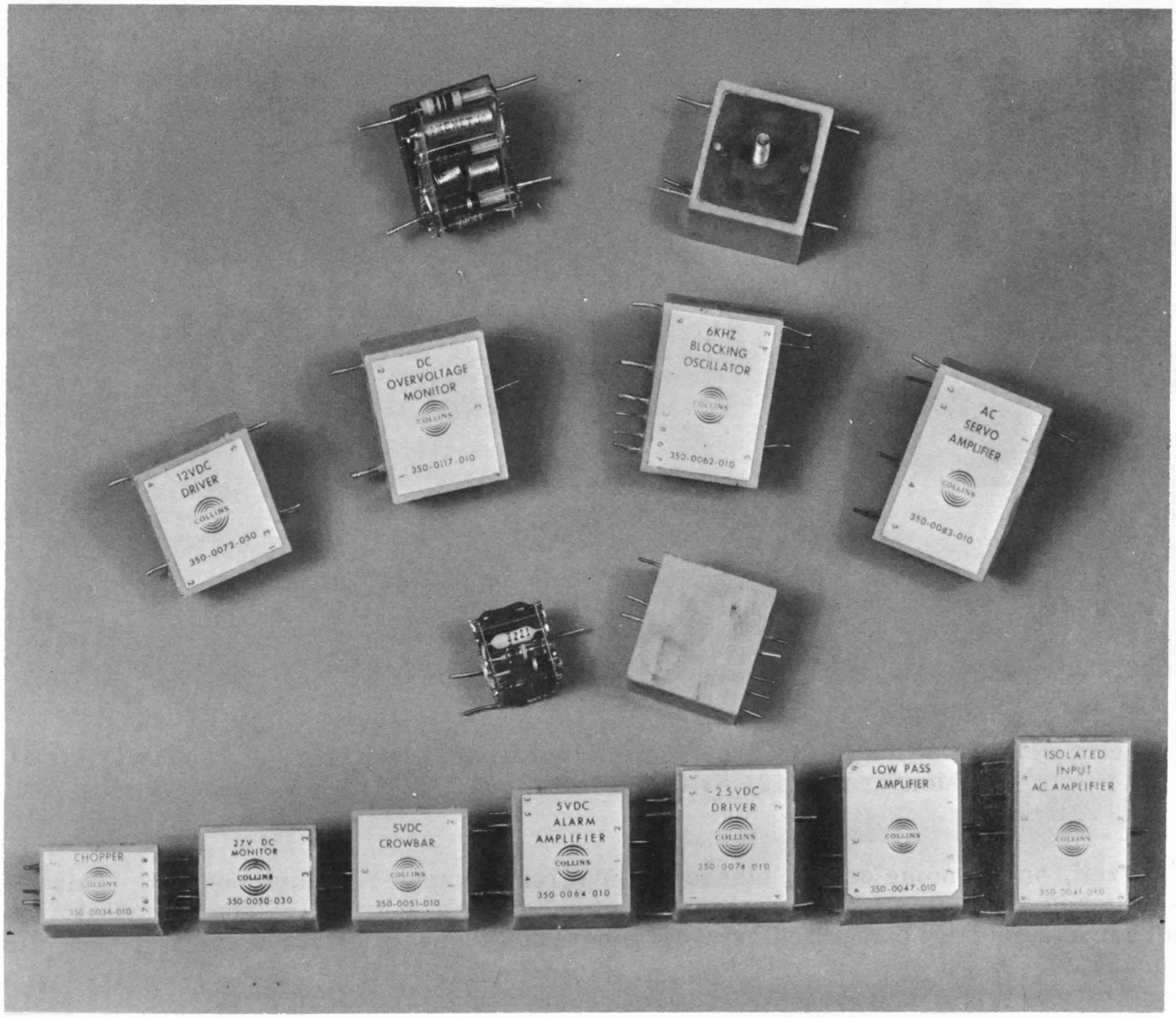


Figure 5-10. Standard Micromodules.

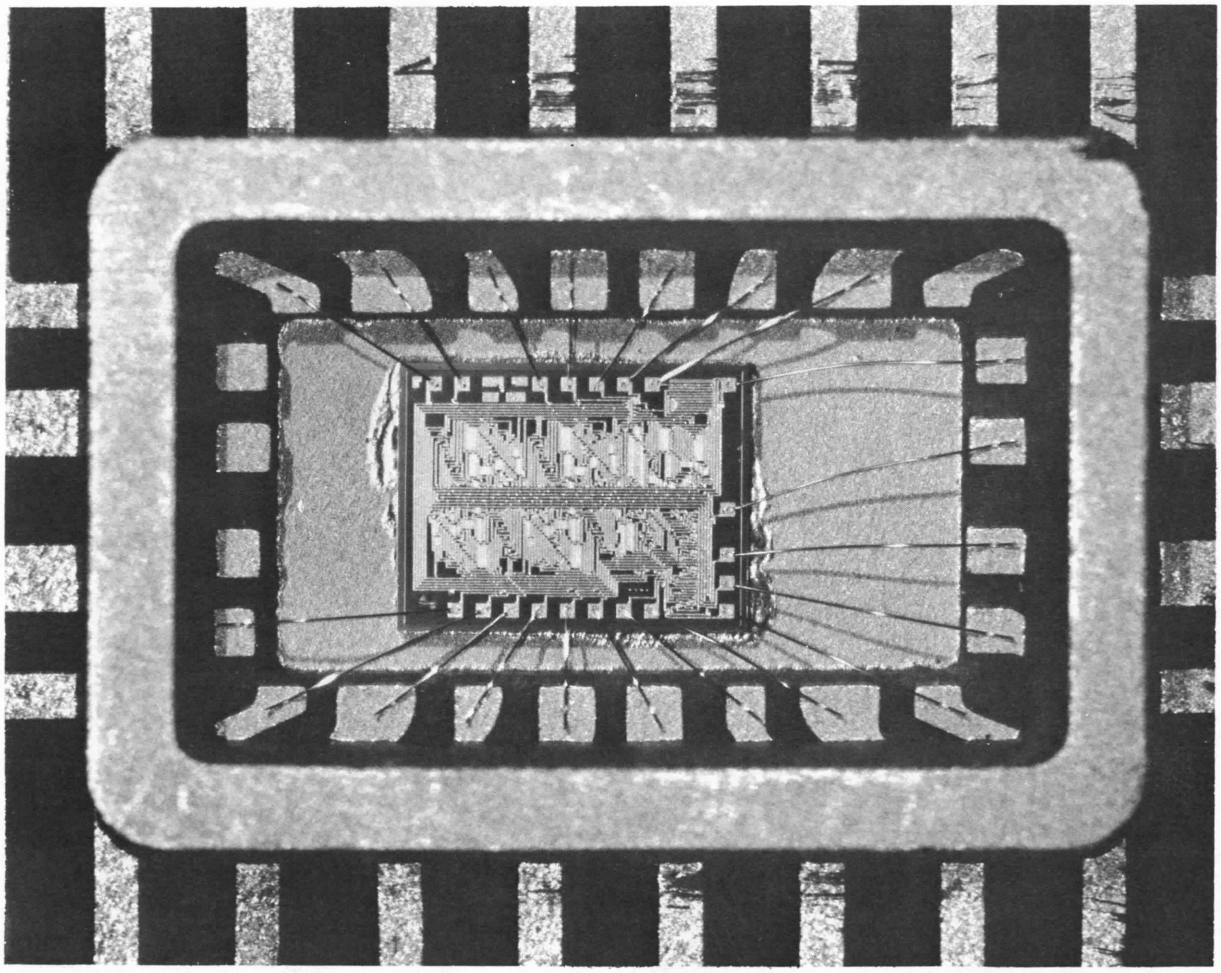


Figure 5-11. Collins MOS Large Scale Integrated Digital Logic Array (Die Chip Measures 0.125 by 0.095 Inch).

mechanized, and in some cases, placed under direct computer on-line control. This facility is established to accomplish all phases of photomask making from the generation of artwork by Gerber numerically controlled artwork generation through prints of the step-and-repeated photomask.

The production management team consists of a department manager, an industrial engineering staff, and floor supervisors. The engineering department defines and develops the processes and equipment to be used. The present engineering staff includes 18 engineers, three of whom have their PhD. The engineers are supported by nine technicians. The size of this group will double during the next 2 years.

Each work center operator receives detailed instructions in the MOS process during a training program and again before operating a new work center. The operator works with a checklist of instructions for each step in the process. Because of the extensive training and thorough operating documentation, new operators can perform their jobs reliably with little or no previous experience.

5.3 SERVICES

During the various phases of this program, there is a need for services to back up the personnel directly concerned with the study. We have and will make available all the facilities necessary to adequately support the effort.

5.3.1 Computer Facility

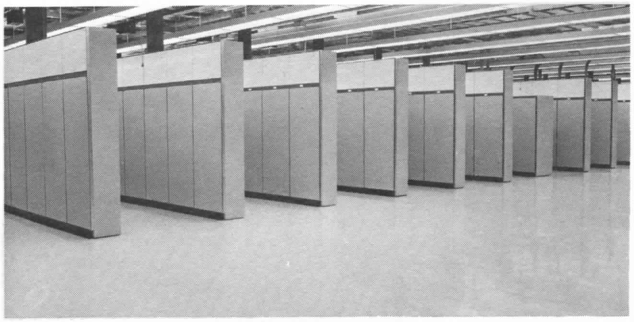


Figure 5-12. Computer Facilities.

The Communications and Data Systems (CDS) Division at Cedar Rapids combine in one centralized location one of the largest facilities in the United States for data processing, message switching, and jf communications. This computer system (figure 5-12) serves as the nerve center for the Company information and control systems. Program Data will be collected here and processed to update Company records concerning inventories, stock schedules, and design and development PERT networks. Other Company records pertaining to sales analysis, standard cost systems, accounts payable, payroll, personnel files, etc, are processed here. At the end of each week, this data is tabulated and distributed to all operating divisions, assuring both management and customer timely, accurate information. Information is supplied directly to the program manager for further distribution.

5.3.2 Libraries

Engineering libraries serve the needs of personnel throughout the Company. The collection consists of texts; periodicals; engineering notebooks; engineering, technical, and research reports; maps; standards; indexes; and abstracting journals. The book collection, comprising approximately 10,000 volumes, reflects the wide range of subject interests within the Company. Basic texts as well as more advanced works are available in the fields of business, industrial management, and pure and applied sciences. The libraries currently receive 200 foremost domestic and foreign periodicals. These journals cover the areas of electronics, electrical engineering, aeronautics, and business. Extensive backfiles of most of these journals are maintained in the library.

Approximately 5,000 classified and unclassified technical reports are contained in the document collection, with about 100 reports being added each week. These include Collins documents and those from electronics companies, educational institutions, research laboratories, and government agencies. A constantly updated file of MIL standards and specifications is maintained.

BLANK PAGE

BLANK PAGE

COLLINS